

ANNUAL REPORT OF THE
BOARD OF REGENTS OF
THE SMITHSONIAN
INSTITUTION

1949

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REPORT OF THE SECRETARY OF THE SMITHSONIAN INSTITUTION

ALEXANDER WETMORE

FOR THE YEAR ENDED JUNE 30, 1949

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith my report showing the activities and condition of the Smithsonian Institution and its bureaus during the fiscal year ended June 30, 1949.

GENERAL STATEMENT

The Institution continued vigorously to pursue its program of activities in "the increase and diffusion of knowledge" as stipulated by its founder, James Smithson. The increase of knowledge is fostered by original scientific researches and explorations in the fields of anthropology, biology, geology, and astrophysics; the diffusion of knowledge, by publications in a number of series that are distributed free to libraries and educational institutions throughout the world, by extensive museum and art gallery exhibits, by the International Exchange Service for the world-wide interchange of scientific and governmental publications, and by a large correspondence, both national and international.

I present first certain general features of the year's activities, together with a summary of the work of the several bureaus of the Institution, to afford a concise picture of the events of the year. Next follow appendixes containing more detailed reports on each bureau, and finally there appears the financial statement of the Executive Committee of the Board of Regents. The appendixes contain reports on the United States National Museum, the National Gallery of Art, the National Collection of Fine Arts, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchange Service, the National Zoological Park, the Astrophysical Observatory, the National Air Museum, the Canal Zone Biological Area, the Smithsonian library, and the publications of the Institution.

When the Smithsonian Institution began its operations more than one hundred years ago, it carried on its research programs largely by subsidizing the work of scientists not on its own staff, and by publishing the results of their work. As these pioneer researches expanded in scope and became somewhat stabilized, bureaus gradually grew up around the Institution, each with its own staff specializing in the work of that particular field. The value of the various activities gradually became known to the Nation, and eventually one by one they were recognized as public necessities by the Congress. Most of them are now supported largely by Government funds although remaining under Smithsonian direction. At present, nearly all the research and exploration of the Institution is done through these bureaus, notably the United States National Museum, the Bureau of American Ethnology, and the Astrophysical Observatory.

As stated in last year's report, the Institution has for many years operated under the handicap of shortages of personnel and of adequate housing space. I reported that the Smithsonian Institution has today the same amount of space that it had in 1911 in which to accommodate four times as many visitors and four times as many museum specimens. Much the same condition still prevails. Some slight gain was apparent in personnel in a few of the scientific divisions, but not sufficient for the prompt execution of essential curatorial work and adequate research on the National collections. The crowded condition, particularly in the buildings of the National Museum, remained unalleviated. In the report of the Director of the Museum it will be noted that there is a considerable decrease in number of specimens accessioned during the year, a decrease which, he says, "may be attributed in part to the inadequacy of available storage facilities for the preservation of such materials." More adequate building space is one of our major needs.

Though hampered by space conditions it should be brought to attention that the Smithsonian Institution continues to grow and to expand its usefulness year by year. In the 5 years during which I have served as Secretary, three additional activities have been added to its responsibilities—the Canal Zone Biological Area, the National Air Museum, and the River Basin Surveys, the latter a unit of the Bureau of American Ethnology. The work of these new activities has notably augmented Smithsonian efforts toward the increase and diffusion of knowledge in widely diversified fields, as will be seen in reading the detailed reports appended hereto. The purpose in calling attention to deficiencies is to emphasize the obvious fact that a growing

institution such as the Smithsonian, of so vital interest and importance to the American people, must receive increased financial support if it is to continue to meet its full obligations and to further the high ideals of its founder, James Smithson, who left his entire fortune in trust to the United States of America for the benefit of all mankind:

**PRESENTATION OF THE WRIGHT BROTHERS' AEROPLANE OF 1903
TO THE UNITED STATES NATIONAL MUSEUM**

On December 17, 1948, the forty-fifth anniversary of the first flight by Wilbur and Orville Wright at Kitty Hawk, N. C., the original aeroplane that made that historic flight became the property of the American people. At a formal ceremony in the Museum attended by many high civil and military officials the plane was presented to the United States National Museum by Milton Wright on behalf of the estate of Orville Wright.

The story of the plane goes back to December 17, 1903, when the Wright Brothers were ready after several years of research and experiment to test out their gasoline-engine-powered biplane at Kitty Hawk on the coast of North Carolina. With Orville at the controls, the machine was released, and after a 40-foot run on the launching track, it lifted into the air in full flight. In Orville Wright's own words:

"The flight lasted only 12 seconds, but it was nevertheless the first in the history of the world in which a machine carrying a man had raised itself by its own power into the air in full flight, had sailed forward without reduction of speed, and had finally landed at a point as high as that from which it started."

Three more flights were made the same day, but after the last flight a strong gust of wind turned the plane over, damaging it so badly that no more trials were made that year. The damaged machine and engine were sent back to the Wrights' workshop in Dayton, and 13 years later were restored, using all the original parts available. The aeroplane was displayed at the Massachusetts Institute of Technology and later at several aeronautical exhibitions. In 1928 Orville Wright had it sent as a loan to the Science Museum at South Kensington, London, England, where it remained on exhibition until World War II. Owing to the danger of damage by bombing, the plane was removed to a safe place for the duration of the war.

When Orville Wright died on January 30, 1948, it was learned from papers in his files that he wished the Kitty Hawk aeroplane to be returned to the United States and placed in the National Museum. The executors of his estate conferred with officials of the Science

Museum and of the Smithsonian Institution, and with the generous cooperation of the British Government the actual transfer of the plane took place in November 1948. It was brought across the Atlantic to Halifax on the *Mauretania*, from there to Bayonne, N. J., on the Navy carrier *Palau*, and to Washington by Navy truck.

At the formal presentation on December 17, 1948, the ceremonies were opened by the Secretary of the Smithsonian Institution. After the invocation by Maj. Gen. Luther D. Miller, Chief of Chaplains, Department of the Army, and greetings by the Presiding Officer, Chief Justice Fred M. Vinson, Chancellor of the Smithsonian Institution, a message from the President of the United States was read by Col. Robert B. Landry, Air Force Aide to the President. His Britannic Majesty's Ambassador, Sir Oliver Franks, K. C. B., C. B. E., then spoke on "Britain and the Wright Brothers," after which the presentation of the aeroplane was made by Milton Wright, of Dayton, Ohio, on behalf of the estate of Orville Wright. Mr. Wright told of his boyhood recollections of his uncles' bicycle shop where the Kitty Hawk plane was fabricated, and concluded thus:

"The aeroplane means many things to many people. To some it may be a vehicle for romantic adventure or simply quick transportation. To others it may be a military weapon or a means of relieving suffering. To me it represents the fabric, the glue, the spruce, the sheet metal, and the wire which, put together under commonplace circumstances but with knowledge and skill, gave substance to dreams and fulfillment to hopes."

The aeroplane was accepted on behalf of the Smithsonian Institution by Chief Justice Fred M. Vinson, Chancellor of the Institution, and the address of acceptance was given by Vice President-Elect Alben W. Barkley, a regent of the Institution. In the course of his address Mr. Barkley expressed one thought that doubtless was in the minds of all participants in the ceremony:

"It is a matter of deep regret to all of us that Orville Wright could not have been here today to see this wide public recognition of achievement, and receive in person the fitting acclaim to his brother, to himself, and to their Kitty Hawk plane. We are grateful to all of those who have made it possible to bring the plane back to its native soil, and especially to the heirs of the estate of Orville Wright, for depositing the Kitty Hawk machine here where all America will have an opportunity to see it, and where all may do it fitting honor."

The Kitty Hawk aeroplane now hangs suspended from the ceiling of the north hall of the National Museum's Arts and Industries Building, where the presentation ceremony was held. Directly back of the main entrance, the plane is the first object to meet the eyes of

the thousands of visitors who throng the Museum daily. As thus displayed it bears the following label:

The Original

WRIGHT BROTHERS' AEROPLANE

The world's first
power-driven heavier-than-air machine in which man
made free, controlled, and sustained flight

Invented and built by Wilbur and Orville Wright
Flown by them at Kitty Hawk, North Carolina
December 17, 1903

By original scientific research the Wright Brothers
discovered the principles of human flight

As inventors, builders, and flyers
they further developed the aeroplane, taught man to fly
and opened the era of aviation

Deposited by the Estate of Orville Wright



"The first flight lasted only twelve seconds, a flight very modest compared with that of birds, but it was nevertheless the first in the history of the world in which a machine carrying a man had raised itself by its own power into the air in free flight, had sailed forward on a level course without reduction of speed, and had finally landed without being wrecked. The second and third flights were a little longer, and the fourth lasted 59 seconds covering a distance of 852 feet over the ground against a 20 mile wind."—WILBUR and ORVILLE WRIGHT.

(From Century Magazine, vol. 76, September 1908, p. 649.)

This is not the final resting place of the plane, however—it is destined eventually to occupy the place of honor in the National Air Museum, the most recent bureau of the Smithsonian Institution. Preliminary plans for the Air Museum envision a special centrally located exhibit area for the Wright aeroplane of 1903, to serve as a memorial to the birth of aviation.

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and, therefore, constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

The following changes occurred during the year in the personnel of the Board of Regents:

On January 20, 1949, Vice President Alben W. Barkley (formerly a regent by appointment from the Senate) became ex officio a member of the Board.

On February 14, 1949, the following regents were appointed from the House of Representatives: Clarence Cannon of Missouri; John M. Vorys of Ohio; and E. E. Cox of Georgia to succeed Samuel K. McConnell of Pennsylvania.

On March 8, 1949, Senators Leverett Saltonstall and Clinton P. Anderson were appointed to succeed Vice President Alben W. Barkley who became an ex officio member of the Board, and Senator Wallace H. White of Maine, retired.

On March 10, 1949, Dr. Jerome C. Hunsaker was appointed a citizen regent from Massachusetts for the statutory term of 6 years, to succeed Frederic C. Walcott, retired.

The roll of regents at the close of the fiscal year, June 30, 1949, was as follows:

Chief Justice Fred M. Vinson, Chancellor; Vice President Alben W. Barkley; members from the Senate: Walter F. George, Clinton P. Anderson, Leverett Saltonstall; members from the House of Representatives: Clarence Cannon, John M. Vorys, E. E. Cox; citizen members: Harvey N. Davis, Arthur H. Compton, Vannevar Bush, Robert V. Fleming, and Jerome C. Hunsaker.

Proceedings.—The Board of Regents held its annual meeting on January 14, 1949. Present: Chief Justice Fred M. Vinson, Chancellor; Representative Clarence Cannon, Representative John M. Vorys, Dr. Arthur H. Compton, Dr. Harvey N. Davis, Dr. Robert V. Fleming, Secretary Alexander Wetmore, and Assistant Secretary John E. Graf.

The Secretary presented his annual report covering the activities of the Institution and its bureaus, including the financial report of the Executive Committee, for the fiscal year ended June 30, 1948, which was accepted by the Board. The usual resolution authorizing the expenditure by the Secretary of the income of the Institution for the fiscal year ending June 30, 1950, was adopted by the Board.

It was announced that in support of the work of the Astrophysical Observatory John A. Roebling had made a further generous gift which is of major importance in carrying on these scientific investigations.

The annual report of the Smithsonian Art Commission was presented by the Secretary and accepted by the Board. A resolution was adopted to reelect the following members for 4-year terms: Archibald

G. Wenley, David E. Finley, Eugene E. Speicher, Paul Manship. The following officers were reelected for the ensuing year: Chairman, Paul Manship; vice chairman, Robert Woods Bliss; secretary, Alexander Wetmore.

The Board was advised that in an attempt to recover the Gellatly art collection from the Secretary in his status of a private individual, though acting as custodian under the Smithsonian Institution, Mrs. Charlayne Gellatly's attorneys had filed action in the District Court of the United States for the District of Columbia on June 18, 1947. Under date of June 17, 1948, Judge J. McGuire rendered a decision that, in the opinion of the Court, there was no merit in Mrs. Gellatly's claims, since it was found that there was a valid gift to the United States by the deceased, John Gellatly, before his death and before his marriage. On July 19, 1948, the attorney for Mrs. Gellatly filed notice of appeal before the United States Court of Appeals for the District of Columbia. Marvin C. Taylor, special attorney, Department of Justice, represented the Institution.

On the evening of March 1, 1949, an informal meeting of the Board was held at dinner in the Main Hall of the Smithsonian Building, with the Chancellor, Chief Justice Fred M. Vinson, presiding. At this meeting heads of the various activities under the Institution presented statements relative to their work. These statements, with the ensuing discussion, provided a general view of the existing operations of the Smithsonian, particularly in the research field.

FINANCES

A statement on finances, dealing particularly with Smithsonian private funds, will be found in the report of the Executive Committee of the Board of Regents, page 143.

APPROPRIATIONS

Funds appropriated to the Institution for the fiscal year ended June 30, 1949, totaled \$2,259,000, allotted as follows:

General administration.....	\$46, 794
National Museum.....	712, 560
Bureau of American Ethnology.....	71, 996
Astrophysical Observatory.....	101, 590
National Collection of Fine Arts.....	32, 543
International Exchange Service.....	68, 938
Maintenance and operation.....	764, 626
Service divisions.....	274, 448
National Air Museum.....	180, 285
Canal Zone Biological Area.....	4, 760
Unallotted.....	460
Total.....	2, 259, 000

In addition \$1,073,500 was appropriated to the National Gallery of Art, a bureau of the Institution but administered by a separate board of trustees; and \$528,848 was provided in the District of Columbia appropriation act for the operation of the National Zoological Park.

Besides these direct appropriations, the Institution received funds by transfer from other Federal agencies, as follows:

From the State Department, from the appropriation Cooperation with the American Republics, 1949, a total of \$97,900 for the operation of the Institute of Social Anthropology, including the issuance of publications resulting from its work.

From the National Park Service, Interior Department, \$118,500 for archeological projects in connection with River Basin Surveys.

VISITORS

The number of visitors to the Smithsonian buildings for the year was 2,606,104, an all-time record of attendance. This was an increase of 212,605 over the previous year's attendance. April 1949 was the month of largest attendance with 371,871 visitors; August 1948, the second largest with 313,364. Records for the five buildings show the following number of visitors: Smithsonian, 494,880; Arts and Industries, 1,148,303; Natural History, 689,233; Aircraft, 198,648; Freer, 75,040.

A summary of attendance records is given in table 1:

TABLE 1.—*Visitors to the Smithsonian buildings during the year ended June 30, 1949*

Year and month	Smithsonian Building	Arts and Industries Building	Natural History Building	Aircraft Building	Freer Gallery of Art	Total
<i>1948</i>						
July.....	61,820	128,635	74,243	24,557	9,510	298,471
August.....	65,412	136,704	75,026	26,672	9,550	313,364
September.....	45,178	90,321	51,839	18,460	7,269	213,067
October.....	34,400	66,320	47,962	13,870	5,460	167,881
November.....	27,380	50,700	39,820	11,833	4,415	134,157
December.....	18,242	42,191	23,419	8,512	3,153	95,517
<i>1949</i>						
January.....	26,748	59,837	37,212	11,085	4,124	139,006
February.....	22,949	54,470	35,220	10,842	4,032	127,513
March.....	25,650	66,814	41,452	12,499	5,092	151,507
April.....	64,804	177,144	97,135	23,532	9,256	371,871
May.....	47,718	142,007	88,029	19,653	6,172	303,579
June.....	54,810	133,151	77,807	17,333	7,007	290,168
Total.....	494,880	1,148,303	689,233	198,648	75,040	2,606,104

¹ Not including 31,249 persons attending meetings after 4:30 p. m.

SIXTEENTH JAMES ARTHUR ANNUAL LECTURE ON THE SUN

In 1931 the Institution received a bequest from James Arthur, of New York, a part of the income from which was to be used for an annual lecture on some aspect of the study of the sun.

The sixteenth Arthur lecture was given in the auditorium of the National Museum on April 14, 1949, by Sir Harold Spencer Jones, Astronomer Royal of Great Britain, the arrangements being made through Dr. S. A. Mitchell, of the Leander McCormick Observatory, University of Virginia. The title of Sir Harold's lecture was, "The Determination of Precise Time," a subject on which he is a world authority. His lecture will be published in full in the Annual Report of the Board of Regents of the Smithsonian Institution for 1949.

SUMMARY OF THE YEAR'S ACTIVITIES OF THE BRANCHES OF THE INSTITUTION

National Museum.—Approximately 446,000 specimens were added to the collections, for the most part as gifts or as transfers from Government agencies, bringing the total number of catalog entries to 31,679,046. Outstanding accessions for the year included: In anthropology, an important collection of 51 artifacts representing the work of American Indians, Eskimo of Alaska, and natives of Pacific islands, given by Georgetown University; 17 gold-embossed silver vessels given by the Government of Tibet to President Truman and in turn presented by him to the Smithsonian Institution; and valuable skeletal remains recovered in northern Australia by Frank M. Setzler, a member of the Commonwealth of Australia-National Geographic Society-Smithsonian Institution Expedition to Arnhem Land; in zoology, mammal specimens from many distant parts of the world including Northern Territory of Australia, Nepal, Malay Peninsula, Korea, Okinawa, Philippine Islands, and New Guinea, 778 birds from Arnhem Land, Australia, and 1,164 from India and Nepal, 14,000 fishes from the Solomon Islands and the East Indies, and 5,000 from the Persian Gulf and the Red Sea; in botany, 2,382 plants of Fiji, 5,854 plants of Colombia, and 2,157 plants of China; in geology, 20 kinds of minerals hitherto unrepresented in the National collections, a 42-carat brazilianite gemstone, the largest ever found in Brazil, an 8,750-gram stony meteorite that fell at Girgenti, Italy, and many thousands of fossil specimens collected by staff members in various parts of the United States; in engineering and industries, the original Wright Brothers' aeroplane of 1903, a collection of electrical measuring instruments, early lamps, and electronic tubes, some of them made in the 1880's, and an exhibit showing the development of electric hearing aids; in history, a group of relics bequeathed by Gen. John J. Pershing, including uniforms, flags, and medals, a noteworthy collection of European gold and silver coins from the fourteenth to the twentieth century presented by Paul A. Straub, of New York City, and a complete set of Allied military currency presented by the Department of the Army.

Field work was conducted in Arnhem Land in northern Australia, India and Nepal, the Persian Gulf and the Red Sea, New Zealand, the Canadian Arctic, nine different countries in South and Central America, and many parts of the United States. The Museum published its Annual Report, 3 Bulletins, 25 Proceedings papers, and 2 papers in the Contributions from the United States National Herbarium. The division of history was elevated to the status of a full department of the Museum, with five divisions—military history, naval history, civil history, numismatics, and philately.

National Gallery of Art.—During the year there were 1,529,568 visitors to the Gallery, an average daily attendance of 4,225. Accessions as gifts, loans, or deposits numbered 1,174, including 10 paintings and 50 prints and drawings from the estate of the late R. Horace Gallatin, and 891 prints and drawings from Lessing J. Rosenwald. Eleven special exhibitions were held at the Gallery, and two traveling exhibitions were circulated to art galleries, museums, and other organizations throughout the country. In response to inquiries received by the Gallery, nearly 1,000 research problems requiring reports were investigated, and advice was given regarding 233 works of art brought to the Gallery for opinion. Numerous books and articles on art subjects were published by staff members. New publications continued to be added to the literature available at the Gallery for purchase by the public. Some 15,000 persons attended the special tours of the Gallery, 20,000 the "Picture of the Week" talks, and 18,000 the lectures in the auditorium. The Gallery's collections of art works has grown so fast that all available exhibition space was in use during the year. To provide for expansion, contracts have been let for the completion of 12 more galleries in unfinished areas of the Gallery building. Some 50,000 persons attended the 46 Sunday evening concerts given in the Gallery's East Garden Court.

National Collection of Fine Arts.—At the annual meeting of the Smithsonian Art Commission of December 7, 1948, a number of paintings were accepted for the National Collection. The Commission passed a resolution calling attention to the inadequacy of the present art exhibition facilities in the National Museum and recommending that the Secretary of the Smithsonian Institution take action to provide proper space for the preservation and exhibition to the public of the National Collection of Fine Arts. Two miniatures were acquired through the Catherine Walden Myer fund. Under the provisions of the Ranger bequest, seven paintings temporarily assigned to various art institutions were recalled for final consideration by the Smithsonian Art Commission. Two of these paintings were accepted for the National Collection, and the others were returned to the institutions to which they were originally assigned. A large

amount of information on art subjects was furnished to visitors in person, as well as by mail and phone. Members of the staff lectured on art topics to several organizations, and six special art exhibitions were held during the year, for most of which catalogs were furnished by the organizations sponsoring the exhibitions.

Freer Gallery of Art.—Additions to the collections included Chinese bronze, jade, lacquer, marble, and painting; Syrian glass; Syrian or Egyptian gold; Arabic manuscript; Persian manuscript, painting, and stone sculpture; Indian painting; and Turkish painting. The work of the professional staff was devoted to the study of new accessions and to research within the collection of Chinese, Japanese, Iranian, Arabic, and Indian materials. Reports were made upon 2,563 objects and 372 photographs of objects submitted to the Gallery for examination, and 369 Oriental language inscriptions were translated. The repair and restoration of the walls of Whistler's Peacock Room were completed early in the year, and work was begun on the ceiling. Visitors to the Gallery numbered 74,846 for the year, and 1,724 came to the Gallery offices for special purposes. Sixteen groups were given instruction in the exhibition galleries by staff members, and 13 lectures were given in art galleries and museums, before clubs, and to various associations.

Bureau of American Ethnology.—Dr. M. W. Stirling, Director of the Bureau, devoted 4 months to a continuation of his archeological work in Panamá in cooperation with the National Geographic Society. Heretofore undescribed ceramic cultures were found at Utivé and Barriles, and much new information was obtained on the classic Chiriquí and Veraguas cultures. Dr. Frank H. H. Roberts, Jr., continued to direct from Washington the very extensive operations of the River Basin Surveys, a unit of the Bureau created to rescue important archeological sites threatened by the construction of dams and the creation of river basin reservoirs. The work was done in cooperation with the National Park Service, the Bureau of Reclamation, the Army Corps of Engineers, and local organizations. Surveys of threatened sites covered 69 reservoir areas in 21 States. Since the program started, 2,107 archeological sites have been located and recorded, and of these, 456 have been recommended for excavation or testing before they are destroyed by construction work. Dr. John P. Harrington continued his revision of the Maya grammar. Toward the end of the year he went to Old Town, Maine, to pursue ethnological and linguistic studies on the Abnaki Indians. Dr. Henry B. Collins, Jr., conducted archeological excavations at Frobisher Bay on Baffin Island in the Canadian Arctic. Ruins were found of old Eskimo semisubterranean houses made of stones, whale bones, and turf, the evidence showing that the site has been occupied succes-

sively by Eskimos of both the prehistoric Dorset and Thule cultures. Dr. William N. Fenton continued his field work and library research on the Iroquois Indians, obtaining the life history of an aged Seneca and recording Seneca rituals, prayers, and legends. Dr. Gordon R. Willey devoted the year to studying and writing up the results of previous field work. His monographic work, "Archeology of the Florida Gulf Coast," was completed and at the close of the year was in process of being published by the Smithsonian Institution.

The Institute of Social Anthropology, an autonomous unit of the Bureau, is financed by State Department funds to carry out cooperative training in anthropological teaching and research with the other American republics. Institute staff members, under the directorship of Dr. George M. Foster, Jr., continued to give courses in anthropology and to conduct cooperative research and field work in Brazil, Colombia, México, and Perú.

The Bureau published its Annual Report and two Publications of the Institute of Social Anthropology. The last two volumes of the Handbook of South American Indians, volumes 5 and 6, were in press at the close of the year.

International Exchanges.—The Smithsonian International Exchange Service is the official United States agency for the interchange of governmental and scientific publications between this country and the other nations of the earth. The Exchange Service handled during the year a total of 840,125 packages of publications, weighing 796,700 pounds. These figures represent an increase over the previous year of 80,006 packages, but a decrease of 15,489 pounds in weight, indicating by the lighter weight per package that most institutions have about completed shipment of material held up during the war. Shipments are now made to all countries except Rumania, and efforts to resume exchanges with that country are being continued. The number of sets of United States official publications sent abroad in exchange for similar publications of other countries is now 96—58 full and 38 partial sets. There are also sent abroad through the Exchange Service 81 copies of the Federal Register and 75 copies of the Congressional Record.

National Zoological Park.—The collection was improved during the year by the addition of a number of rare animals. At the close of the fiscal year there were 3,724 specimens in the collection, an increase of 927 over the previous year. These represented 755 different species, an increase of 65. Among the rare or unusual animals received by gift, exchange, or purchase were the rare Meller's chameleon, a spectacled bear, a pair of pigmy marmosets—smallest of all monkeys, an African two-horned rhinoceros, a pair of wombats, a pigmy anteater, orang-utans, and chimpanzees. The total number of creatures

born or hatched at the Zoo was 157—56 mammals, 62 birds, and 39 reptiles. Personnel recruitment and training for the organization progressed satisfactorily, and the most needed repairs and minor improvements to buildings and grounds were carried out. The year's total of visitors to the Zoo was the largest ever recorded—3,346,050, an increase of more than 300,000 over the previous year. Groups from schools, some as far away as Maine, Florida, Texas, and California, numbered 1,844, aggregating 93,632 individuals.

Astrophysical Observatory.—Year-long tests at the three most promising sites for a new high-altitude solar observing station indicate that the best skies prevail at the Clark Mountain, Calif., site, the second-best site being Pohakuola, Hawaii. Estimates of the cost of establishing a field station on Clark Mountain, however, proved to be in excess of available funds, forcing postponement of building operations. Data and tables were prepared which simplify computations at the field observing stations by eliminating the tedious curve-plotting process heretofore used in obtaining the air mass. Daily observations of the solar constant of radiation were continued at the Montezuma, Chile, and Table Mountain, Calif., stations. Intercomparisons between the substandard silver-disk pyrheliometer S. I. No. 5 and the instruments in use at Miami, Montezuma, and Table Mountain show no material changes in constants, confirming the adopted scale of pyrheliometry. Special radiation measurements started in 1945 at Camp Lee, Va., under contract with the Office of the Quartermaster General, were continued there, half of the year by the Observatory and half by the Quartermaster Board; similar measurements were also made at Miami, Fla., and at Montezuma, Chile. The work of the Division of Radiation and Organisms has been concerned chiefly with reorganizing and reequipping the laboratories. Besides new office space which has been established, five rooms are being converted into constant-condition rooms for biological experimentation, and four chemistry laboratories will be available. In addition, a photographic laboratory, an X-ray room, a cytology laboratory, an electronics laboratory, and two general laboratories are being arranged.

National Air Museum.—The Air Museum was given the responsibility of receiving, bringing to Washington, and preparing for exhibition the original Wright Brothers aeroplane of 1903, presented to the National Museum in December 1948. A storage depot to be used by the Air Museum until it has a building of its own was acquired in November 1948 in the former Douglas Aircraft plant at Park Ridge, Ill. There a field organization was installed, and the Air Museum assumed custody of the storage facility itself and the large collection of planes and other aeronautical material stored there by the U. S. Air Force for the Museum. The Advisory Board held three meetings

during the year which were devoted mainly to advancing the acquisition of a building site and a suitable museum building in the Washington area. The Museum expects during the coming year to submit to Congress a report regarding sites and a building, the preliminary study of which has been prepared in cooperation with the Public Buildings Administration. Among outstanding accessions of the year were the *Swoose*, the historic B-17-D bomber that served throughout World War II from Bataan to the defeat of Japan, presented by the city of Los Angeles; Maj. Alford Williams' renowned *Gulphawk-2* presented by the Gulf Oil Co.; a Japanese Baka Bomb, or "suicide plane," transferred by the Department of the Navy; and 10 scale models of recent types of Naval aircraft received from the manufacturers who produced the original planes. New accessions totaled 122 objects from 40 different sources.

Canal Zone Biological Area.—A new building for woodworking and carpenter shops and for living quarters for the warden-caretaker was completed during the year, the old quarters being converted into a two-room laboratory unit. Work on the new 14,000-gallon water tank was halted by heavy rains but can be completed with 2 or 3 weeks of dry weather. The most urgent needs are the fireproofing of existing buildings and the construction of a new six-room laboratory and storage building. Twenty-nine scientists representing many different organizations worked at the laboratory during the year, and their contributions have added materially to our knowledge of tropical life. Among the interesting researches were the work of Drs. Scholander and Walters of the Arctic Research Laboratory at Point Barrow, Alaska, on the metabolic reactions to temperature in various animals and plants in order to obtain a tropical counterpart for similar work on Arctic forms in Alaska; the studies of Drs. Clark and Soper of the Research Laboratory of Eastman Kodak on the effects of tropical conditions on photographic equipment and materials, including color film; and the Resident Manager's own special studies, particularly the long-term termite-resistance tests.

PUBLICATIONS

In carrying out the diffusion of knowledge, the Institution issues eight regular series of publications and six others that appear less frequently. All these series, embodying the results of Smithsonian researches, are distributed free to more than a thousand libraries, both here and abroad, as well as to a large list of educational and scientific organizations. The findings of Smithsonian scientists, chiefly in the fields of anthropology, biology, geology, and astrophysics, are therefore made readily available to all through this wide free distribution.

A total of 71 separate volumes and pamphlets were issued during the past year. Among the outstanding publications to appear were Dr. Henry Field's compilation in the Smithsonian Miscellaneous Collections entitled "Contributions to the Anthropology of the Soviet Union," which presents, for the first time in English, accounts of recent findings in this little-known area; a revised edition of the popular handbook of the National Aircraft Collection, which is in effect a brief history of aeronautics from the mythical flying horses of antiquity to the supersonic jet planes of today; two more volumes in the famous series of Life Histories of North American Birds, prepared by A. C. Bent, bringing to 17 the number so far issued in the series; and a paper by Jason R. Swallen on new grasses from several countries of South and Central America, in the Contributions from the United States National Herbarium.

The total number of copies of publications in all series distributed during the year was 267,491. A complete list of the year's publications will be found in the report of the Chief of the Editorial Division, Appendix 12.

LIBRARY

Of the 57,671 publications received by the Smithsonian library during the year, 7,287 came as gifts from many different donors. Another 17,713 were periodicals mostly received in exchange for Smithsonian publications from research institutions and other scientific and educational organizations throughout the world. Containing the record of progress in science and technology, these periodicals are indispensable in the prosecution of the Institution's own work.

Increasingly heavy demands upon reading and reference services of the library were noted during the year, the interlibrary loans totaling 2,619 publications to 89 different libraries. The new position of assistant librarian in charge of the Astrophysical Observatory library was filled by the promotion of an acquisitions assistant.

New exchanges arranged during the year numbered 338; 6,884 volumes and pamphlets were cataloged, and 31,184 cards were added to catalogs and shelflists; 1,060 volumes were sent to the bindery, and 1,026 were repaired in the Museum.

At the close of the year, the library's holdings totaled 921,206 volumes, more than half of which are housed in the Library of Congress as the Smithsonian Deposit.

Respectfully submitted.

ALEXANDER WETMORE, *Secretary.*

APPENDIX 1

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operations of the United States National Museum for the fiscal year ended June 30, 1949.

COLLECTIONS

Approximately 446,000 specimens (88,000 less than last year) were incorporated into the National collections during the year and were distributed among the six departments as follows: Anthropology, 4,099; zoology, 279,621; botany, 38,708; geology, 109,499; engineering and industries, 2,610; and history, 11,104. The decrease in the number of specimens accepted for the Museum's collections may be attributed in part to the inadequacy of available storage facilities for the preservation of such materials; consequently, a finer screening of collections from prospective donors is now mandatory. Most of the accessions were acquired as gifts from individuals or as transfers from Government departments and agencies. The complete report on the Museum, published as a separate document, includes a detailed list of the year's acquisitions, of which the more important are summarized below. Catalog entries in all departments now total 31,679,046.¹

Anthropology.—The most noteworthy additions to the archeological collections were as follows: A black-figured Attic lecythus of the fifth century, B. C., presented to President Harry S. Truman as a token of gratitude from the people of Greece and lent by the President; 11 gold-plated ornaments from Veraguas, Panamá, and 2 gold fishhooks from Colombia, a gift from Karl P. Curtis; and 47 prehistoric earthenware vessels from the Valley of Nasca, Perú, presented to the late Gen. John J. Pershing by former Peruvian President Augusto B. Leguia and donated by General John J. Pershing.

Handicrafts and material culture of many of the world's peoples were represented in the additions to the ethnological collections. An unusually important collection of 51 specimens representing the work of American tribes of the Great Plains and the Great Lakes, of Arizona and New Mexico, as well as of the Eskimo of Alaska, of the Igorot of the Philippine Islands, and of the Marquesans and Maori of the

¹ The revised tabulation of the National collection of insects during the past year, in addition to the normal increment, has increased last year's total by more than 4,400,000 specimens.

Southeast Pacific, assembled over a period of more than a century, was presented by Georgetown University. President Harry S. Truman presented to the Smithsonian Institution 17 gold-embossed silver vessels received at the White House as a gift from the Government of Tibet in appreciation of an American gift of wireless receiving and transmitting sets made during World War II. Included are two butter lamps and stands, four teacup stands and covers, two bowls for grain offerings, one teapot, and two beer mugs, all decorated in gold-embossed designs derived from Chinese-Tibetan folklore and Buddhist religious art. A collection of 287 folk, costume, and historical portrait dolls, representing the native dress of peoples of many lands, was received as a bequest from the late Mrs. Frank Brett Noyes. The Don Diego Columbus mahogany table, traditionally known as the writing desk of Diego Columbus, was conditionally bequeathed by Mrs. Edith Keyes Benton. This table had been preserved for centuries in the cathedral of Santo Domingo City and was presented by Archbishop Nouel to Commander Frederick L. Benton, U.S.N., in recognition of his work in Santo Domingo during the influenza epidemic of 1918. One of the rarest of musical instruments, a musical gong, *kyung*, carved from white marble, was presented by Ju Whan Lee, director of the Korean Court Music Conservatory at Seoul, Korea.

The largest accession received by the division of physical anthropology consisted of the skeletal remains recovered in northern Australia by Frank M. Setzler, a member of the Commonwealth of Australia-National Geographic Society-Smithsonian Institution Expedition to Arnhem Land. Australian skeletal material available for study in the United States is rather limited. Four casts of African fossil primates, which illustrate certain characteristics of antecedent specialization, were also acquired during the year.

Zoology.—The collections made by the Museum staff detailed to the Arnhem Land field expedition, under the joint sponsorship of the Commonwealth of Australia, National Geographic Society, and the Smithsonian Institution, have added many previously unrepresented forms of animal life to the National collections. These collections included not only vertebrates but invertebrates as well.

Accessions that enhanced the usefulness of the mammalian collection came from the Northern Territory of Australia, Nepal, Malay Peninsula, Korea, Okinawa, Philippine Islands, New Guinea, and New Hampshire. Field work financed wholly or in part by the W. L. Abbott fund resulted in the addition of birds not hitherto represented in the National collection. Included among these accessions were 2,815 skins and 38 eggs of Colombian birds; 900 skins, 24 skeletons, and 2 sets of eggs of Panamanian birds; 778 bird skins, many of which were not represented in the collection, as well as 51 skeletons and 2 eggs

from Arnhem Land, Australia; and 1,164 bird skins procured by the joint National Geographic Society-Yale University-Smithsonian Institution Expedition to India and Nepal. Other accessions comprised 611 bird skins from Nyasaland; 177 birds and 1 egg from northeastern Venezuela; 171 bird skins from Pacific War areas; and 125 bird skins from Korea.

Snakes, lizards, and frogs from Arnhem Land, amphibians from Perú, reptiles and amphibians from Honduras, and a general collection from Virginia and North Carolina constituted the most important additions to the herpetological collection.

The most noteworthy accessions received by the division of fishes were nearly 14,000 specimens from the Solomon Islands and the East Indies, which were presented by Dr. Wilbert M. Chapman; 14,300 from Arnhem Land; and approximately 5,000 from the Persian Gulf and the Red Sea, resulting from a survey sponsored by the Arabian-American Oil Co. Other important collections of fishes came from Puerto Rico, Panamá, British Columbia, and Florida.

Approximately 25,000 miscellaneous insects from South Pacific Islands came to the Museum by transfer from the U. S. Commercial Co. Among other large lots were approximately 12,000 flies; 3,500 chalcidoid wasps; 500 beetles; and some 53,000 insects transferred from the United States Bureau of Entomology and Plant Quarantine.

During the year considerable significant material was added to the marine invertebrate collection, of which the most important accessions were 11,765 miscellaneous invertebrates from the Department of Zoology, University of California; 70 lots of paratypes, hypotypes, and topotypes of hydroids from the Allan Hancock Foundation, University of Southern California; 760 marine invertebrates from California and Mexico; 709 specimens from Bahama Islands; 1,781 from Pacific Islands and California; 452 from the Persian Gulf and the Red Sea; and 859 from Arnhem Land. By transfer from the Office of Naval Research, the Museum acquired 3,668 invertebrates from Point Barrow, Alaska. The United States Geological Survey transferred 568 specimens from the Marianas Islands.

A rare deep-water *Pleurotomaria*, dredged at a depth of 160 fathoms off Natal, South Africa, and presented by Dr. Cecil von Bonde, constituted the most notable accession received by the division of mollusks. From other sources the division received 250 Peruvian terrestrial and fresh-water mollusks and 540 marine mollusks from Canton Island, and 150 Japanese land mollusks. Exchanges brought to the Museum approximately 1,080 shells from Spain and lesser numbers from South Africa, Italy, and Cuba. By transfer the Museum received about 1,200 mollusks obtained in the Caroline Islands from the United States Geological Survey; approximately 30,600 specimens

from the Naval Medical Research Institute; and 600 marine and land shells of the Solomon Islands from the Naval Medical School. Members of the staff obtained about 1,200 mollusks in Arnheim Land and some 1,500 in the region of the Persian Gulf and the Red Sea.

Botany.—As exchanges, the National Herbarium received 2,382 plants, comprising a collection made in Fiji by Dr. A. C. Smith, from the Arnold Arboretum of Harvard University; 5,854 plants of Colombia from the Facultad de Agronomía, Universidad Nacional, Medellín; and 2,157 Chinese plants from the National Szechwan University. The Division of Rubber Plant Investigations, United States Department of Agriculture, transferred 865 plants from eastern Colombia. The Oficina de Estudios Especiales, Mexico City, presented 394 Mexican grasses. A noteworthy gift of 295 ferns of Micronesia came to the Herbarium from the Bernice P. Bishop Museum, Honolulu, and Dr. Gunnar Degelius, University of Uppsala, presented 602 lichens from various localities.

Geology.—Gifts and exchanges contributed to the growth of the mineral collections. More than 20 kinds of minerals hitherto unrepresented in the collections were received. Forty exceptionally good examples of rare secondary uranium minerals from Katanga, Belgian Congo, as well as other unusual minerals were added to the Roebling collection. A fine collection of rare copper sulfates from Chuquicamata, Chile, was presented by the Chile Exploration Co. Included among the additions to the Canfield collection were a gem-quality golden beryl crystal weighing over 1,800 grams from Brazil and an unusually large zircon crystal from Australia. The Chamberlain bequest provided funds for the purchase of a 42-carat brazilianite gemstone, the largest as yet found in Brazil. An 8,750-gram stony meteorite, which fell at Girgenti, Italy, was received as a gift from Dr. Stuart H. Perry, and other meteorites were acquired either as gifts or in exchange.

Several large collections of invertebrate fossils were presented to the Museum, three of the larger lots being 7,500 Middle Ordovician fossils, mostly bryozoans, from O. C. Cole, Kenyon, Minn.; 2,150 Pennsylvanian fossils from Robert Stark, Grapevine, Tex.; and 10,000 fossil mollusks from A. L. Bowsher. Types and paratypes of Upper Cretaceous trilobites, Tertiary mollusks, Pennsylvanian goniatites, Ordovician invertebrates, and Cretaceous Foraminifera were included in other accessions. Through funds provided by the Walcott bequest, the Museum acquired 40,000 invertebrate fossils from the Devonian, Mississippian, and Pennsylvanian deposits in west Texas, New Mexico, and Arizona collected by Associate Curator A. L. Bowsher and William Allen; 25,000 Paleozoic fossils from Texas and Oklahoma collected by Curator G. A. Cooper and Associate Curator A. R.

Loeblich; 2,500 Middle Ordovician fossils collected by Dr. Cooper in Tennessee and Virginia; and 2,000 Permian and Jurassic ammonites and brachiopods from Sicily. As usual the year's accessions included a number of transfers from the United States Geological Survey.

A nearly complete skeleton of the Triassic phytosaur *Machaeroprotopus gregorii*, from the Chinle formation near St. Johns, Ariz., excavated and transferred to the Museum by the United States Geological Survey, constitutes the outstanding acquisition of the year in vertebrate paleontology. Through the Walcott funds there were received articulated skeletal remains of the condylarth *Meniscotherium robustum* and the complete skeleton of a large ichthyodectid fish. Outstanding gifts include specimens of the Devonian arthrodiran fish *Eudinichthys terrilli*, a partial skeleton of the Pleistocene jaguar *Panthera augusta*, an incomplete skull of the Pleistocene walrus *Odobenus virginianus*, and a portion of the skull of a Miocene tapir. The Smithsonian River Basin Surveys transferred mammalian fossils from Eocene and Oligocene deposits of Wyoming and Montana.

Engineering and industries.—The presentation of the historic aeroplane invented and built by Wilbur and Orville Wright and flown by them at Kitty Hawk, N. C., on December 17, 1903, was witnessed by 1,000 or more distinguished guests at the formal ceremony held in the north entrance hall of the Arts and Industries Building of the United States National Museum on December 17, 1948. The presentation was made by Milton Wright, of Dayton, Ohio, on behalf of the estate of Orville Wright. The Chancellor of the Smithsonian Institution, Chief Justice Fred M. Vinson, accepted the Wright Brothers' aeroplane on behalf of the Nation, and the formal acceptance address was delivered by Vice President-Elect Alben W. Barkley.

A collection of electrical measuring instruments, early lamps, and electronic tubes, some of which were constructed in the 1880 decade, was presented by the Weston Electrical Instrument Corp. The Museum is indebted to the United States Signal Corps Laboratories for an exhibit illustrating radar and microwave radio-relay communication. From the Cork Institute of America the section of wood technology received 100 samples and 9 photographs which illustrate the production and utilization of cork bark. Etchings and serigraphs by Forain, Margo, Velonis, Detwiller, and Kainen were added to the graphic arts collection through the Dahlgreen fund. A Marcy Sciopticon Magic Lantern, a kerosene-lamp projector, patented 1868-69, was the most interesting accession in the photographic section. The division of medicine and public health received from Telex, Inc., a number of devices that show the development of electric hearing aids.

History.—Several unusual items were added during the past year to the National collection of American antiques and personal relics, and of these the spirit set and silverware owned by the Maryland surveyor Andrew Ellicott (1754–1820) are the oldest. A marble slab from the Temple of Wingless Victory on the Athens Acropolis, presented to President Truman by a Greek delegation on March 28, 1949, as a token of gratitude from the people of Greece, was lent by the President. The most interesting additions to the costumes collection were a parasol made of pheasant feathers and an old bonnet of the type known as “calash.” The outstanding accessions to the military collection were the relics bequeathed by Gen. John J. Pershing, comprising personal uniforms, presentation flags, medals, decorations, and other mementos of his military service. Forty-four portraits of World War II heroes painted by Joseph Cummings Chase were presented to the Museum by the artist.

The collection of gold and silver coins, chiefly European issues dating from the fourteenth to the twentieth century, which was received as a gift from Paul A. Straub, of New York City, constitutes the most noteworthy accession acquired by the division of numismatics in recent years. A complete set, in duplicate, of Allied military currency was presented by the Department of the Army.

EXPLORATION AND FIELD WORK

Staff specialists in the departments of anthropology, zoology, botany, and geology were engaged during the year in field work in South, Central, and North America, New Zealand, and Australia.

The four staff members—Frank M. Setzler, head curator of anthropology; Dr. David H. Johnson, associate curator of mammals; Herbert G. Doignan, associate curator of birds; and Dr. Robert R. Miller, associate curator of fishes—who participated in the technical work of the Commonwealth of Australia-National Geographic Society-Smithsonian Institution Expedition to Arnhem Land under the leadership of Charles P. Mountford, returned to Washington, D. C., late in 1948 following completion of the field work. The base camp of the expedition, which had been established April 4, 1948, on Groote Eylandt in the Gulf of Carpentaria, was moved during July 1948 to Yirrkala on the beach of Arafura Sea near the northeastern corner of Arnhem Land. A third camp was established September 21, 1948, at Oenpelli on East Alligator River near the foot of the high Arnhem Land escarpment. The entire party returned to Darwin in November to pack the collections and field equipment for shipment to the participating institutions.

During the first 3 months of 1949, Dr. T. Dale Stewart, curator of physical anthropology, was engaged in taking anthropometric measurements of some 200 Mayan-speaking Indians in the highlands of Guatemala. Most of this field study was carried on at Soloma in the Department of Huehuetenango, and at Santa Clara la Laguna in the Department of Sololá. A secondary project was the examination of skeletal remains at archeological sites in the highlands.

As in the previous year, Dr. Waldo R. Wedel, associate curator of archeology, was detailed to the River Basin Surveys under the Bureau of American Ethnology to supervise field and laboratory operations in the Missouri Valley.

The National Geographic Society-Yale University-Smithsonian Institution Expedition to India and Nepal, which was directed by S. Dillon Ripley, brought back important collections of birds and mammals from the Karnali Valley in western Nepal and the Kosi Valley in eastern Nepal—regions rarely visited by naturalists.

For 5 months during the middle of 1948, Donald S. Erdman, division of fishes, participated in a fishery survey in the Persian Gulf and Red Sea under the auspices of the Arabian-American Oil Co.

At the invitation of the Plywoods-Plastics Corp., Dr. Henry W. Setzer, associate curator, division of mammals, worked in Costa Rica and obtained specimens of mammals and birds in the valleys of the Río Estrella and the Río Turrialba.

Dr. A. Wetmore and W. M. Perrygo conducted ornithological field work in the eastern section of the Province of Panamá, Republic of Panamá, a region they had not explored on previous trips. The field work of M. A. Carriker, Jr., in the Río Sinú region of northwestern Colombia, resulted in the preparation of one of the most complete collections of birds thus far obtained in the area adjacent to Panamá. Charles O. Handley, Jr., temporarily employed as assistant curator of birds, departed from Washington in March 1949 under a cooperative arrangement with the Weather Bureau to study the birds and mammals in one area of the Canadian Arctic Archipelago.

Botanical field projects participated in by the staff included the following: After adjournment of the Second South American Botanical Congress held at Tucumán, Argentina, E. P. Killip, head curator of botany, and Dr. Lyman B. Smith, associate curator of phanerogams, made collections in northwestern Argentina; large numbers of plants were assembled by Mr. Killip in the Santiago-Valparaiso region of Chile, and other specimens were subsequently obtained at Cali, Medellín, and Bogotá, Colombia; Dr. Smith collected plants in the vicinity of São Paulo and Río de Janeiro, Brazil.

Following the adjournment of the Seventh Pacific Science Congress held between February 2 and 22, 1949, Dr. E. H. Walker, associate

curator of phanerogams, remained in New Zealand for about 6 weeks at the invitation of the University of New Zealand to carry on botanical field work on the two main islands and on Stewart Island. Jason R. Swallen, curator of grasses, at the request of Dr. C. L. Lundell, director of the Texas Research Foundation, made a survey of the grasses of the Kingsville region, Texas. George A. Llano, associate curator of cryptogams, is making a special study of the ecology of the lichens of the Arctic slopes of the Brooks Mountains in northern Alaska under a project sponsored by the Arctic Institute of North America. Paul S. Conger, associate curator of diatoms, devoted 2 months during the summer of 1948 to an investigation of the ecology of diatoms at the Chesapeake Biological Laboratory, Solomons Island, Md. Research Associate F. A. McClure continued his field studies of American bamboos in Guatemala, El Salvador, Honduras, Puerto Rico, Jamaica, and Trinidad.

A wide variety of paleontological field work financed by the Walcott bequest enabled the staff to obtain new materials for the collections. Included among these additions are fossil fishes from the Green River Eocene beds in northeastern Utah and the Pierre Cretaceous deposits in eastern Wyoming excavated by Dr. D. H. Dunkle and A. C. Murray; Eocene mammalian fossils from the Bridger Basin in western Wyoming collected by Dr. C. L. Gazin; Paleocene mammalian fossils found by Dr. C. L. Gazin and F. L. Pearce in the San Juan Basin of northwestern Utah; Permian and Mississippian invertebrate fossils obtained by Dr. G. A. Cooper and Dr. A. R. Loeblich, Jr., in Texas and Oklahoma; Devonian, Mississippian, and Pennsylvanian fossils from New Mexico and Texas collected by A. L. Bowsher and William Allen; and Jurassic microfossils from Montana, Wyoming, and South Dakota obtained by Dr. A. R. Loeblich, Jr., and Dr. Ralph W. Imlay.

PUBLICATIONS

Thirty-one Museum publications were issued during the year: 1 Annual Report, 3 in the Bulletin series, 25 in the Proceedings, and 2 numbers of the Contributions from the United States National Herbarium. A list of these is given in the complete report on Smithsonian publications, appendix 12. Especially noteworthy are two numbers of A. C. Bent's Life Histories of North American Birds: one on the nuthatches, wrens, thrashers, and their allies, the other on the thrushes, kinglets, and their allies—completing 17 volumes in this popular series. The eighteenth is now in press.

The distribution of volumes and separates to libraries and other institutions and to individuals aggregated 66,459 copies.

CHANGES IN ORGANIZATION

One important change in the organization of the United States National Museum was effected during the year. On August 16, 1948, the division of history was raised to the status of a department. Charles Carey, who received his first appointment to the Museum staff on November 2, 1920, was named acting head curator of the department of history. The functions of this department were allocated to five divisions—military history, naval history, civil history, numismatics, and philately.

Respectfully submitted.

REMINGTON KELLOGG, *Director.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit, on behalf of the Board of Trustees, the twelfth annual report of the National Gallery of Art, for the fiscal year ended June 30, 1949. This report is made pursuant to the provisions of section 5 (d) of Public Resolution No. 14, Seventy-fifth Congress, first session, approved March 24, 1937 (50 Stat. 51).

ORGANIZATION

The statutory members of the Board of Trustees of the National Gallery of Art are the Chief Justice of the United States, the Secretary of State, the Secretary of the Treasury, and the Secretary of the Smithsonian Institution, ex officio. The five general trustees continuing in office during the fiscal year ended June 30, 1949, were Samuel H. Kress, Ferdinand Lamot Belin, Duncan Phillips, Chester Dale, and Paul Mellon. The Board of Trustees held its annual meeting on May 3, 1949. Samuel H. Kress was reelected President and Ferdinand Lamot Belin Vice President, to serve for the ensuing year. Donald D. Shepard continued to serve during the year as Advisor to the Board.

All the executive officers of the Gallery continued in office during the year:

Huntington Cairns, Secretary-Treasurer.
David E. Finley, Director.
Harry A. McBride, Administrator.
Huntington Cairns, General Counsel.
John Walker, Chief Curator.
Macgill James, Assistant Director.

The three standing committees of the Board, as constituted at the annual meeting May 3, 1949, were as follows:

EXECUTIVE COMMITTEE

Chief Justice of the United States, ex officio, Fred M. Vinson, Chairman.
Samuel H. Kress, Vice Chairman.
Ferdinand Lamot Belin.
Secretary of the Smithsonian Institution, Dr. Alexander Wetmore.
Paul Mellon.

FINANCE COMMITTEE

Secretary of the Treasury, ex officio, John W. Snyder, Chairman.

Samuel H. Kress, Vice Chairman.

Ferdinand Lammot Belin.

Chester Dale.

Paul Mellon.

ACQUISITIONS COMMITTEE

Samuel H. Kress, Chairman.

Ferdinand Lammot Belin, Vice Chairman.

Duncan Phillips.

Chester Dale.

David E. Finley, ex officio.

On June 30, 1949, the Government employees on the staff of the National Gallery of Art totaled 309, as compared with 312 employees as of June 30, 1948. The United States Civil Service regulations govern the appointment of employees paid from appropriated public funds.

Throughout the year a high standard of operation has been maintained by all departments of the Gallery in the protection of the Gallery's collections of works of art and the maintenance of the Gallery building and grounds.

APPROPRIATIONS

For the fiscal year ended June 30, 1949, the Congress of the United States appropriated for the National Gallery of Art the sum of \$1,073,500 to be used for salaries and expenses in the operation and upkeep of the Gallery, the protection and care of works of art, and administrative and other expenses. This amount includes the regular appropriation of \$966,000, and a supplemental appropriation of \$107,500. The supplemental appropriation was made to provide \$4,600 to meet in part an increase in the rates for electric current, which could not be foreseen by the Gallery and estimated for at the time the 1949 budget was submitted to the Congress; and the balance of \$102,900 was necessary to meet the pay increases, effective July 11, 1948, amounting to \$330 per annum to each employee as authorized by Public Law 900, Eightieth Congress.

From these appropriations the following expenditures and encumbrances were incurred:

Personal services.....	\$940, 100. 00
Printing and binding.....	6, 626. 95
Supplies, equipment, etc.....	126, 739. 30
Unobligated balance.....	33. 75
Total.....	1, 073, 500. 00

ATTENDANCE

During the fiscal year 1949 there were 1,529,568 visitors to the Gallery, an average daily attendance of about 4,225.

From March 17, 1941, the day on which the National Gallery of Art was first opened to the public, to June 30, 1949, there have been 15,070,976 visitors to the Gallery.

ACCESSIONS

There were 1,174 accessions by the National Gallery of Art, as gifts, loans, or deposits, during the fiscal year. Most of the paintings and a number of the prints were placed on exhibition.

PAINTINGS

During the fiscal year the Board of Trustees of the National Gallery of Art received 10 paintings from the Estate of the late R. Horace Gallatin. The paintings are as follows:

<i>Artist</i>	<i>Title</i>
Jean-Charles Cazin.....	The Windmill.
Jean-Baptiste-Camille Corot.....	River View.
Charles-Francois Daubigny.....	Landscape with Figures.
Diaz de la Pena.....	Forest Scene.
Jules Dupre.....	The Old Oak.
Francesco Guardi.....	The Rialto Bridge, Venice.
Henri-Joseph Harpignies.....	Landscape.
School of Claude Lorrain.....	Harbor at Sunset.
Jean-Francois Millet.....	The Bather.
Theodore Rousseau.....	Landscape with Boatman.

A painting by Murillo, "The Return of the Prodigal Son," given by the Avalon Foundation, was accepted by the Board of Trustees on December 10, 1948. At the same time the Board accepted the portrait of Daniel Boardman, by Ralph Earl, from Mrs. W. Murray Crane; "Interior of a Church," by Pieter Neeffs, from Senator Theodore Francis Green of Rhode Island; and two paintings, "Repose," by John Singer Sargent, and "Head of a Girl," by James Abbott McNeill Whistler, from Curt H. Reisinger. On December 22, 1948, the Board of Trustees accepted from Dr. G. H. A. Clowes a painting, "Allegory," Venetian School about 1500, and from Vladimir Horowitz a painting, "Head of a Young Girl," by Renoir. The Board of Trustees accepted from Miss Georgia O'Keeffe on March 8, 1949, a gift of the following three paintings:

<i>Artist</i>	<i>Title</i>
Marsden Hartley.....	Landscape No. 5.
Arthur G. Dove.....	Moth Dance.
Georgia O'Keeffe.....	To be selected later.

During the fiscal year, the portrait of Captain Patrick Miller by Raeburn, previously on loan, was given to the Gallery by Mrs. Dwight Davis.

SCULPTURE

On December 10, 1948, the Board of Trustees accepted from Stanley Mortimer, Jr., a "Portrait Bust of a Member of the Order of San Iago" attributed to Leone Leoni, which had previously been on loan to the Gallery. At the same time the Board accepted from Miss Mildred Howells a portrait medallion of her father, William Dean Howells, and herself, by Augustus Saint-Gaudens, to be held for a National Portrait Gallery.

PRINTS AND DRAWINGS

A gift from Lessing J. Rosenwald of 309 additional prints and drawings was accepted on December 10, 1948, to be added to the Lessing J. Rosenwald Collection. At the same time, two volumes of "The Georgics" of Virgil with 119 illustrations by Andre Dunoyer de Segonzac were accepted as a gift from the artist. This gift was inspired by an earlier gift to the Gallery of a collection of Segonzac's prints and drawings made in memory of the late Frank Crowninshield. The Board of Trustees, during the fiscal year, received 50 prints and drawings from the collection of the late R. Horace Gallatin. On March 8, 1949, the Board accepted from Miss Georgia O'Keeffe three water colors by John Marin entitled "Movement, Boat and Sea, Deer Isle, Maine," "White Mountain Country, Summer," and "Storm over Taos, New Mexico." The Board of Trustees accepted from Mr. Rosenwald on May 3, 1949, 582 additional prints and drawings. Received during the fiscal year from George Matthew Adams were 20 etchings by Alphonse Legros.

PHOTOGRAPHS

The Board of Trustees on March 8, 1949, accepted from Miss Georgia O'Keeffe a key set of photographs, consisting of about 1,500 prints, by Alfred Stieglitz.

EXCHANGE OF WORKS OF ART

During the fiscal year 1949 the Board accepted the offer of Chester Dale to exchange the portrait of Ralph Waldo Emerson by Sully, which was being held for the National Portrait Gallery, for the portrait of the Sicard David Children by Sully, which was then on loan to the Gallery. The Board also accepted the offer of Lessing J. Rosenwald to exchange the prints "Sacrifice to Priapus," by Jacopo de Barbari, "Conversion of St. Paul," by Lucas van Leyden, and

"Solomon Worshipping Idols," by the Master M. Z., for superior impressions of like prints now included in the Rosenwald Collection at the National Gallery of Art.

WORKS OF ART ON LOAN

During the fiscal year 1949 the following works of art were received on loan by the National Gallery of Art:

<i>From</i>	<i>Artist</i>
Chester Dale, New York, N. Y.:	
Picador.....	Domergue.
Mrs. Philip Lydig.....	Zuloaga.
San Sepulveda.....	Zuloaga.
La Rubia del Abanico.....	Zuloaga.
Mrs. Brooks Goddard, Paris, France (via the National Collection of Fine Arts):	
Musical Inspiration.....	Romaine Brooks Goddard.
The Balcony.....	Romaine Brooks Goddard.
Sketch.....	Romaine Brooks Goddard.
Self-Portrait.....	Romaine Brooks Goddard.
Alfred Stieglitz Collection:	
(Miss Georgia O'Keeffe, New York, N. Y.)	
Chimneys and Water Tower.....	Demuth.
A Cow's Skull with Red.....	O'Keeffe.
Line and Curve.....	O'Keeffe.
Chauncey Stillman, New York, N. Y.:	
A Halberdier.....	Pontormo.
George Matthew Adams, New York, N. Y.:	
3 etchings.....	Alphonse Legros.
C. S. Gulbenkian, Lisbon, Portugal:	
28 pieces of Egyptian sculpture.	
3 pieces of eighteenth-century French fur- niture.	
1 fourteenth-century Arabian bottle.	
1 sixteenth-century Persian rug.	
7 eighteenth-century French books.	
The Italian Government:	
A marble statue of David.....	Michelangelo.
Robert Woods Bliss, Washington, D. C.:	
32 objects of Pre-Columbian art.	

LOANED WORKS OF ART RETURNED

The following works of art on loan were returned during the fiscal year 1949:

<i>To</i>	<i>Artist</i>
Chester Dale, New York, N. Y.:	
On the Beach.....	Winslow Homer.
Mme. Charlotte Fuerstenberg, at New York, N. Y.:	
Sea at Estaque.....	Cezanne.

Anonymous loan:

- Paradise Valley----- John La Farge.
 Robert Woods Bliss, Washington, D. C.:
 16 objects of Pre-Columbian art.
 Peabody Museum, Harvard University, Cambridge, Mass.:
 70 objects of Pre-Columbian art.

WORKS OF ART LOANED

During the fiscal year 1949, the Gallery loaned the following works of art for exhibition purposes:

<i>To</i>	<i>Artist</i>
Albright Art Gallery, Buffalo, N. Y.:	
Joseph Widener-----	Augustus John.
Art Institute of Chicago, Chicago, Ill.:	
Alexander Hamilton-----	Trumbull.
William Thornton-----	Stuart.
Columbus Gallery of Fine Arts, Columbus, Ohio:	
Abraham Lincoln-----	Healy.
Corcoran Gallery of Art, Washington, D. C.:	
The White Girl-----	Whistler.
Dallas Museum of Fine Arts, Dallas, Tex.:	
George Washington (Vaughan-Sinclair)-----	Stuart.
Dayton Art Institute, Dayton, Ohio:	
Lackawanna Valley-----	Inness.
Fort Worth Art Association, Fort Worth, Tex.:	
Breezing Up-----	Winslow Homer.
Metropolitan Museum of Art, New York, N. Y.:	
Captain Charles Stewart-----	Sully.
Pack Memorial Library, Asheville, N. C.:	
Thomas Dawson-----	Mather Brown.
Henry Laurens-----	Copley.
Andrew Jackson-----	Earl.
Williamina Moore-----	Feke.
General William Moultrie-----	Charles Willson Peale.
John C. Calhoun-----	Rembrandt Peale.
John Baptista Ashe-----	Stuart.
Matilda Caroline Cruger-----	Stuart.
Francis Hopkinson-----	Sully.
Ann Biddle Hopkinson-----	Sully.
Josias Allston-----	Theus.
William Rogers-----	Trumbull.
Portraits, Inc., New York, N. Y.:	
Mrs. Chester Dale-----	Bellows.
Mr. Chester Dale-----	Bellows.
Scott and Fowles, New York, N. Y.:	
Joseph Widener-----	Augustus John.

EXHIBITIONS

During the fiscal year 1949 the following exhibitions were held at the National Gallery of Art:

American Paintings from the Collection of the National Gallery of Art. Exhibition of American paintings, featuring a group of portraits from Pocahontas to General Eisenhower. Continued from previous fiscal year, through July 11, 1948.

American Folk Art. Exhibition consisting of 104 water-color renderings from the Index of American Design. July 18 to September 7, 1948.

American Graphic Art from the Eighteenth Century to the Present Day. Selection from the collections of the Library of Congress, the Smithsonian Institution, and the National Gallery of Art. September 19 to November 14, 1948.

Paris the Favorable Climate. Exhibition of prints and drawings by Bonnard, Vuillard, Maurice Denis, Andre Dunoyer de Segonzac, and Matisse, arranged in memory of Frank Crowninshield. November 21, 1948, to January 11, 1949.

Michelangelo's "David." Lent to the National Gallery of Art by the Italian Government. January 24 to June 28, 1949.

Gulbenkian Collection of Egyptian Sculpture. Lent for an indefinite period to the National Gallery of Art by C. S. Gulbenkian. Opened January 30, 1949.

Studies of Medieval Cathedrals. Exhibition of photographic studies lent to the National Gallery of Art by Clarence Ward, head of the Department of Fine Arts, Oberlin College. January 30 to February 13, 1949.

Gulbenkian Collection of Eighteenth Century French Objects. Additions to earlier loan by C. S. Gulbenkian, on exhibition at the National Gallery of Art for an indefinite period. Opened February 20, 1949.

American Paintings from the Collection of the National Gallery of Art. February 20 to April 10, 1949.

Early Italian Engraving. Exhibition of early Italian engravings, lent to the National Gallery of Art by various museums and anonymous lenders. April 17 to June 19, 1949.

R. Horace Gallatin Collection. Exhibition of prints bequeathed to the National Gallery of Art by Mr. Gallatin. Opened June 26, 1949.

The following exhibitions were displayed in the cafeteria corridor of the National Gallery of Art during the fiscal year 1949:

Whistler Prints. Rosenwald Collection; one gift of Myron A. Hofer. Continued from previous fiscal year through July 18, 1948.

Audubon Prints. Mrs. Walter B. James Collection. July 20 to December 12, 1948.

Index of American Design. Water-color renderings of early American toys. December 13, 1948, to February 15, 1949.

Index of American Design. Water-color renderings of early American furniture and textiles. February 16 to March 28, 1949.

Legros Prints. George Matthew Adams Collection. March 29 to May 15, 1949.

Seymour Haden Prints. Rosenwald Collection and gift of Miss Elisabeth Achelis. May 16 to June 12, 1949.

Ostade Prints. Rosenwald Collection and gift of Mrs. Addie Burr Clark. Opened June 13, 1949.

TRAVELING EXHIBITIONS

Rosenwald Collection.—Special exhibitions of prints from the Rosenwald Collection were circulated to the following places during the fiscal year 1949:

Kenneth Taylor Galleries, Nantucket, Mass.:

26 French prints.

July 26 to August 23, 1948.

Watkins Gallery, American University, Washington, D. C.:

26 French prints.

October 13 to 30, 1948.

Los Angeles County Museum, Los Angeles, Calif.:

20 Blake prints.

October 1948.

Wyncote Woman's Club, Wyncote, Pa.:

11 prints.

October 17 to 23, 1948.

Rutgers College, New Brunswick, N. J.:

9 Italian prints.

October 1948.

Fogg Museum of Art, Harvard University, Cambridge, Mass.:

1 Rembrandt drawing.

November 1948.

Museum of Modern Art, New York, N. Y.:

1 Munch print.

November 1948 to January 1949.

Walters Art Gallery, Baltimore, Md.:

6 Gavarni drawings.

January 22 to March 6, 1949.

Walters Art Gallery, Baltimore, Md.:

5 miniatures.

January 27 to March 13, 1949.

City Art Museum, St. Louis, Mo.:

17 prints.

March 1949.

Institute of Contemporary Arts, Washington, D. C.:

11 Klee prints.

March 21 to April 22, 1949.

Philadelphia Museum of Art, Philadelphia, Pa.:

3 Lehmbruck prints.

May 1949.

Art Gallery of Toronto, Toronto, Canada:

67 prints.

May 1949.

Index of American Design.—During the fiscal year 1949 exhibitions from this collection were shown at the following places:

Library of Congress, Washington, D. C.	Stephens College, Columbia, Mo.
Western Reserve Historical Society, Cleveland, Ohio.	Brown University, Providence, R. I.
Shaker Village Work Camp, Pittsfield, Mass.	Fort Valley State College, Fort Valley, Ga.
New York State Historical Association, Cooperstown, N. Y.	Washington College, Chestertown, Md.
Damariscotta Information Bureau, Damariscotta, Maine.	Everhart Museum, Scranton, Pa.
University of Tennessee, Knoxville, Tenn.	Art Gallery, Grand Rapids, Mich.
Wustum Museum of Fine Arts, Racine, Wis.	Florida Agricultural and Mechanical College, Tallahassee, Fla.
City Art Museum, St. Louis, Mo.	Farnsworth Museum, Rockland, Maine.
William Rockhill Nelson Gallery, Kansas City, Mo.	Tuskegee Institute, Tuskegee, Ala.
Munson-Williams-Proctor Institute, Utica, N. Y.	Young Playways, Inc., Washington, D. C.
Toledo Museum of Art, Toledo, Ohio.	Smith College, Northampton, Mass.
Mint Museum, Charlotte, N. C.	Prairie View University, Prairie View, Tex.
Museum of Fine Arts, Montgomery, Ala.	University of North Dakota, Grand Forks, N. Dak.
Schenectady Museum, Schenectady, N. Y.	American University, Washington, D. C.
University of Oklahoma, Norman, Okla.	Rockford Art Association, Rockford, Ill.
University of Michigan, Ann Arbor, Mich.	Sweet Briar College, Sweet Briar, Va.
North Carolina College, Durham, N. C.	Arkansas Agricultural, Mechanical and Normal College, Pine Bluff, Ark.
Art Institute, Zanesville, Ohio.	Alfred University, Alfred, N. Y.
Atlanta University, Atlanta, Ga.	Fisk University, Nashville, Tenn.
Currier Gallery of Art, Manchester, N. H.	St. Paul Public Library, St. Paul, Minn.
	Spelman College, Atlanta, Ga.
	Arnot Art Gallery, Elmira, N. Y.
	Kenneth Taylor Galleries, Nantucket, Mass.

CURATORIAL ACTIVITIES

The Curatorial Department accessioned 1,118 new gifts to the Gallery during the fiscal year. Advice was given in the case of 233 works of art brought to the Gallery for opinion, and 58 visits were made by members of the staff in connection with proffered works of art. Almost 1,000 research problems requiring reports were investigated in response to inquiries received by the Gallery. During the year, 16 individual lectures were given by members of the curatorial staff, both at the Gallery and elsewhere. In addition Miss Elizabeth Mongan gave a seminar at Alverthorpe, Jenkintown, Pa., for Swarth-

more College honor students; Charles Seymour, Jr., gave a course at Johns Hopkins University on Renaissance Art; and Charles M. Richards gave a survey course on art history under the auspices of the Department of Agriculture. Miss Mongan also made the arrangements for Arthur M. Hind's American lecture tour, in connection with the publication of Part II of his "Early Italian Engraving," under Gallery auspices. Mr. Seymour served on three and Miss Mongan on two art juries.

Special installations were prepared for: the Michelangelo "David" lent to the National Gallery of Art through the courtesy of the Italian Government; 28 pieces of Egyptian sculpture lent to the Gallery by C. S. Gulbenkian placed on exhibition in January 1949; and eighteenth-century furniture and books also lent by Mr. Gulbenkian. The cataloging and filing of photographs in the George Martin Richter Archive continued to make progress, with the gradual enlargement of the collection.

Further activities of the department are indicated under the heading of "Publications."

RESTORATION AND REPAIR OF WORKS OF ART

Necessary restoration and repair of works of art in the Gallery's collections were made by Stephen S. Pichetto, Consultant Restorer to the Gallery, until his death in January 1949. No successor to Mr. Pichetto has as yet been appointed, but necessary minor repairs on the works of art have been continued under the care of Mr. Pichetto's residual staff. All work was completed in the Restorer's studio in the Gallery, with the exception of the restoration of two paintings, work on which is being completed in the New York studio of S. S. Pichetto, Inc.

PUBLICATIONS

During the year Mr. Cairns published two books, "The Limits of Art," Pantheon Books, Inc., and "Legal Philosophy from Plato to Hegel," Johns Hopkins Press. He also edited a volume entitled "Lectures in Criticism," Pantheon Books, Inc., and contributed an introduction to "Epicurus, My Master," by Max Radin, University of North Carolina Press. He also contributed articles and reviews to the Columbia Law Review, Human Events, Saturday Review of Literature, New York Herald Tribune, Baltimore Evening Sun, Law and Contemporary Problems, The Scientific Monthly, and to the volume *El Actual Pensamiento Juridico de los Estados Unidos*, Buenos Aires.

A series of 12 articles on masterpieces in the Gallery, prefaced by one entitled "New Friends for Old Masters," is being published by John Walker in the Ladies Home Journal. An article by Mr.

Walker, "The Art of Duplicating Great Art," appeared in *Vogue* on August 15, 1948, and another, "American Masters in the National Gallery," in the *National Geographic Magazine* in September 1948. Mr. Walker also contributed two book reviews, the first reviewing Bernard Berenson's "Aesthetics and History in the Visual Arts" to the October 1948 *Gazette des Beaux-Arts*, and the second, entitled "The Philosophy of a Connoisseur," a review of Mr. Berenson's "Sketch for a Self-Portrait," to the *New York Times* for April 24, 1949. Charles Seymour, Jr., published two articles, "Note on the Relationship between an Illustration by Travies de Villers and Daumier's 'Le Fardcau'," in the *Journal of the Walters Gallery* for 1948, and in the *Summer Bulletin of the Columbus Gallery of Fine Arts* the text of the address given by him for the inauguration of a group of sculpture by Georg Ehrlich in the Columbus Gallery of Fine Arts. Printing of "Masterpieces of Sculpture from the National Gallery of Art," a volume prepared by Mr. Seymour, was begun during the summer of 1949. Mrs. Fern R. Shapley has written two book reviews, a review of Bernard Berenson's "Aesthetics and History" which is to be published in the next number of the *College Art Journal*, and one on Evelyn Sandberg-Vavala's "Uffizi Studies" published in the January 1949 *Gazette des Beaux-Arts*. Miss Elizabeth Mongan contributed six articles for the volume honoring Paul Sachs; an article for the Color Print Society on "Rockport," a colored lithograph by Stella Drabkin; descriptions of 27 illuminated miniatures to Professor Faye for the second edition of Seymour de Ricci's "Census of Manuscripts in America." An article on Rowlandson by David Keppel was published in the winter, 1949, number of *The Art Quarterly*. An article by James W. Lane entitled "Religious Art Exhibit" appeared in the *Interracial Review*, and one on "Contemporary Religious Sculpture Exhibition" in the *Catholic University Bulletin*; he contributed two book reviews on "Van Eyck's the Holy Lamb," by Leo Van Puyvelde, and "Robert Louis Stevenson," by David Daiches, to the *Catholic World*, and one on "American Landscape Painting," by Wolfgang Born, to the *Magazine of Art*. Charles M. Richards wrote a report on a code for intermuseum loans for the American Association of Museums.

An illustrated catalog of the Gulbenkian Egyptian sculpture was issued for the opening of the exhibition, and Mr. Seymour prepared a pamphlet on the Michelangelo "David," which was placed on sale during its exhibition. The book of illustrations of the Mellon Collection went to press in the late spring of 1949; work on the new National Gallery of Art catalog is at an advanced stage.

The Publications Fund during the past fiscal year has continued to add new subjects to the supply of inexpensive color reproductions

offered to the public, including 11" x 14" color prints and color post cards. Five large collotype reproductions supplemented the already long list of subjects available. A silk-screen print of an anonymous fifteenth-century colored woodcut from the Rosenwald Collection was also published.

The Gallery is continuing to meet the demand for illustrated catalogs of its various collections. The Mellon catalog is in process of publication, a third printing of the Kress catalog ordered, and a fifth edition of the Chester Dale catalog was published during the year.

Two new publications were issued this year: an "Arts and Crafts Bibliography," by Erwin O. Christensen, and a catalog of the "Egyptian Sculpture from the Gulbenkian Collection." A group of engraved Christmas cards was added to the usual series of color and Rosenwald subjects.

Final negotiations have been made for the printing in gravure of the book, "Masterpieces of Sculpture from the National Gallery of Art," and it will be available by October 1949; the publisher now has the final manuscript for "Made in America," by Mr. Christensen; the Gallery received a stock of "Popular Art in the United States," also by Mr. Christensen, which will go on sale on July 4, 1949; and "Pictures from America," by John Walker, will shortly be published.

EDUCATIONAL PROGRAM

During the year approximately 15,000 persons attended the General, Congressional, and Special Topic Tours, while over 20,000 attended the Picture of the Week. More than 18,000 came to hear the lectures and other programs in the auditorium. At least two-thirds of this lecture audience were regular attendants at these Sunday afternoon lectures. Many of them brought out-of-town visitors, and stated that this lecture series was becoming one of the Capital's chief Sunday attractions. The motion picture, "The National Gallery of Art," continues to be popular with clubs, educational organizations, and similar groups. During the past 12 months, 19 persons borrowed this film.

The publication of the monthly Calendar of Events, announcing Gallery activities, including notices of exhibitions, lectures, Gallery talks, tours, and concerts was continued during the year by the Educational Department. About 3,900 of the Calendar of Events are mailed each month.

LIBRARY

A total of 283 books, 221 pamphlets, and 31 periodicals were given to the Gallery; 494 books, 18 pamphlets, and 282 periodicals were purchased, and 40 subscriptions to periodicals were purchased. Exchanges with other institutions included 47 books, 114 pamphlets,

13 periodicals, and 420 bulletins. Of the 1,762 books borrowed and returned during the year, the Library of Congress lent 1,676 books to the Gallery on the usual interlibrary loan basis, and the remaining 86 books were borrowed from 25 public and university libraries.

INDEX OF AMERICAN DESIGN

During the year the Index of American Design continued to expand as the result of gifts and exchanges. Three hundred and thirty-six persons studied Index material at the Gallery; of this number, 301 were new users and 25 revisited the collection for study purposes. The use of photographs of Index drawings was increased by about 40 percent, with 1,796 photographs being sent out on loan, exchange, or purchase. Fifty exhibitions of original water-color renderings were circulated in 25 States.

PRESIDENT TRUMAN'S INAUGURAL RECEPTION

On January 20, 1949, the President's Inaugural Reception was held in the National Gallery of Art. The Seventh Street ground floor and main floor lobbies were especially furnished and decorated for the occasion; the rotunda and the two garden courts were appropriately decorated with flowers; under arrangements made by the White House staff, a platform was built in the West Sculpture Hall where the President addressed the guests who could not be received personally in the West Garden Court. Three sections of the Marine Band Orchestra played during the reception. The total number of guests was approximately 8,000.

CUSTODY OF GERMAN PAINTINGS

On April 6, 1949, the Gallery accepted custody of the 97 paintings from Berlin museums which had been on an exhibition tour of the United States, part of the group of 202 German paintings stored in the Gallery building by the Department of the Army from December 1945 to March 1948. After the last exhibition of this collection of paintings in Toledo, Ohio, the collection was brought to Washington and stored in the Gallery for about 2 weeks pending final shipping arrangements. On April 20, 1949, the collection was delivered to the Army for return to the American Zone in Germany.

The exhibition of the Berlin paintings in 13 museums throughout the United States resulted in the collection of \$303,605.35 through admission fees and voluntary contributions for the relief of German children in the American Zone in Germany. These funds were deposited with the Gallery and were later disbursed in accordance with instructions received from the Department of the Army. During the tour 1,307,001 persons viewed the paintings, in addition to 964,970

who saw them during the time the paintings were on exhibition at the National Gallery of Art in Washington.

CUSTODY OF GERMAN SILVER

On January 7, 1949, the Gallery returned to the Department of the Army for transport to Germany the 44 sealed cases containing silverware and glassware and belonging to the Hohenzollern family. The cases had been stored in the Gallery since April 11, 1947.

CUSTODY OF WHITE HOUSE FURNITURE

On November 24, 1948, the Gallery accepted custody of certain items of paintings, sculpture, and furniture belonging to the White House for storage in the building until the repairs to the White House are completed.

Shipments of these items started on December 3, 1948, and continued for several days thereafter. At the present time there are 76 works of art—paintings and sculpture—stored in the Gallery's storage rooms and 25 vanloads of furniture stored in the packing space on the main floor.

The necessary arrangements for fire prevention, inspection, and fumigation have been established and are being carried out.

NEW CONSTRUCTION

During the past fiscal year, the Committee on the Building approved the construction in the southwest moat of a small workroom for the use of the gardening staff in maintaining and growing certain plants for the garden courts and landscaping. Later, when funds become available, it is planned to construct two small greenhouses adjacent to this workroom.

The growth of the Gallery's collections of works of art has been so rapid that all available exhibition space is now being utilized. As a matter of fact there are already several paintings which cannot be exhibited because there is no space in the present galleries. For this reason the Committee on the Building recommended that, to take care of the most urgent needs, the unfinished spaces 61-66 and 68-70, on the main floor, be completed as soon as funds are available. These galleries will be used for new acquisitions of paintings in the American and British schools and will also make possible some rearrangement in galleries already finished so as to make available additional space therein.

The Committee on the Building also recommended that the so-called copyists' room be finished to furnish office space for the Educational Department, which is now operating in rather cramped quarters.

Funds have been generously made available from private sources to complete this work, and contracts have been entered into with Eggers

and Higgins, Architects, and Vermilya-Brown Company, General Contractors, for the completion of 12 galleries in these unfinished areas. The floor plan has been approved, and bids are now being taken from subcontractors. It is anticipated that actual construction will begin in August 1949 and that the work will be completed by May 1950.

CARE AND MAINTENANCE OF THE BUILDING

The usual routine work in connection with the care and maintenance of the building and its mechanical equipment was carried on throughout the year.

The three older refrigeration compressors were completely dismantled and overhauled, including the purge compressors. Three chilled-water pumps, including the electric motors, were completely overhauled and realigned by the mechanical staff. Twelve supply fans were cleaned and repainted to protect them against corrosion. The structural steel base for the large 400-horsepower motor driving No. 2 Worthington refrigeration machine was strengthened in order that this large motor would remain in alignment. To correct serious leaks in two of these machines, the technical staff successfully made and installed the necessary parts.

The cornice metal lining at the top of the exterior wall of the building developed leaks, and approximately 50 percent of the joints in the metal lining were cleaned and soldered.

In connection with the Inaugural Reception, the technical staff installed floodlights on three sides of the building, assisted the personnel of the U. S. Army Signal Corps in the installation of a loud-speaker system on the main floor, and installed extra electric lines and water lines for the use of the caterer. The maintenance staff erected extensive checking facilities for the proper care of wraps.

Twelve new display cases were constructed by the staff for the Gulbenkian Exhibition.

Care and improvement of the Gallery grounds and other miscellaneous work progressed satisfactorily. Potted plants, totaling 2,366, which were used for decoration in the two garden courts, were grown in the southwest moat. In addition, over 350 large pots of chrysanthemums were also grown in this moat area, and these plants provided the decoration for the two garden courts during the months of October and November.

COMMITTEE OF EXPERT EXAMINERS

During the year the United States Civil Service Commission's Committee of Expert Examiners, composed of staff members of the Gallery, aided in the drafting of standards for Civil Service positions in which a knowledge of the history of art is a basic requirement. The

Committee also performed preliminary work in the preparation of the examination announcement for art positions which was distributed by the Civil Service Commission with a closing date of April 19, 1949. From this examination registers of eligibles will be established for appointment to art positions in the Gallery and elsewhere in the Government. This will give the present incumbents, most of whom are serving indefinite war-time appointments, an opportunity to attain permanent status, and will also make available a greater number of qualified candidates.

OTHER ACTIVITIES

Forty-six Sunday evening concerts were given during the fiscal year, all concerts being held in the East Garden Court. A Mozart Festival of six concerts was given in the autumn with the highest attendance rate for the season. The five Sunday evenings in May were devoted to the Gallery's annual American Music Festival. An estimated 50,000 persons attended these concerts.

During the year the photographic laboratory of the Gallery made 17,709 prints, 1,342 black-and-white slides, 1,005 color slides, 3,873 negatives, in addition to infrared photographs, ultraviolet photographs, X-rays, and color separation negatives.

A total of 3,500 copies of press releases, 128 special permits to copy paintings in the National Gallery of Art, and 117 special permits to photograph in the Gallery were issued during the year.

OTHER GIFTS

Gifts of books on art and related material were made to the Gallery library during the year by Paul Mellon and others. Gifts of money during the fiscal year 1949 were made by the Avalon Foundation and The A. W. Mellon Educational and Charitable Trust, and a cash bequest was received from the Estate of the late William Nelson Cromwell.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

An audit of the private funds of the Gallery has been made for the fiscal year ended June 30, 1949, by Price Waterhouse & Co., public accountants, and the certificate of that company on its examination of the accounting records maintained for such funds will be forwarded to the Gallery.

Respectfully submitted.

HUNTINGTON CAIRNS, *Secretary.*

THE SECRETARY,
Smithsonian Institution.

APPENDIX 3

REPORT ON THE NATIONAL COLLECTION OF FINE ARTS

SIR: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1949.

THE SMITHSONIAN ART COMMISSION

The twenty-sixth annual meeting of the Smithsonian Art Commission was held in the Regents' Room of the Smithsonian Building, on Tuesday, December 7, 1948.

The members present were: Paul Manship, chairman; Alexander Wetmore, secretary (member, ex officio); George Hewitt Myers; George H. Edgell; Lloyd Goodrich; John Taylor Arms; Archibald G. Wenley, Gifford Beal, and Robert Woods Bliss. Thomas M. Beggs, Director of the National Collection of Fine Arts, and John E. Graf, Assistant Secretary of the Smithsonian Institution, were also present.

The Commission recommended the reelection of Archibald G. Wenley, David E. Finley, Eugene E. Speicher, and Paul Manship for the usual 4-year period.

The following officers were reelected for the ensuing year: Paul Manship, chairman; Robert Woods Bliss, vice chairman; and Dr. Alexander Wetmore, secretary.

The following were reelected members of the executive committee for the ensuing year: David E. Finley, chairman, Robert Woods Bliss, and Gilmore D. Clarke. Paul Manship, as chairman of the Commission, and Dr. Alexander Wetmore, as secretary of the Commission, are ex officio members of the executive committee.

The Secretary summarized the status of exhibition and storage of the art objects of the National Collection of Fine Arts which at present are housed in space intended for the natural history collections in the Natural History Building. A separate building for the art collections is included in the Smithsonian building program, but funds for the development of plans have not been made available.

The following resolution, offered by Mr. Goodrich, was passed unanimously:

Resolved, That whereas the art collections in the custody of the National Collection of Fine Arts are exhibited in an entirely inadequate manner, the Smithsonian Art Commission recommends that the Secretary of the Smithsonian Institution

take all action necessary to provide space and facilities necessary to the preservation and proper exhibition of these art collections to the public.

The formal meeting was adjourned at 11:45 at which time the members assembled in the main hall of the Smithsonian Building to pass on the works of art which had been offered during the year. The following action was taken:

Accepted for the National Collection of Fine Arts

Miniature, water color on ivory, Robert Broome, by an unknown artist, and a shell cameo. Gifts of Miss Helen Munroe.

Painting, Tiger and Cub, ink and water color on paper, and scroll, ink on paper, by Mr. Whang, Jang Har. Gifts of the artist as a token of friendship and gratitude to the American people from the people of Korea through the Korean Commission in Washington.

Miniature, water color on ivory, My Uncle Charles, by Albert Colfs. Gift of the artist.

Oil, Portrait Group (Benjamin West, Frank W. and Henry T. C. Wilkin), by Frank W. Wilkin (1791-1842). Gift of Mrs. Mabel Wiles.

Oil, Thomas Moran, by Howard Russell Butler, N. A. (1856-1934). Bequest of Miss Ruth Moran. A signed palette and brushes used by Thomas Moran, and a photogravure of the artist, were included in the bequest.

Oil, A Reading, by Thomas W. Dewing, N. A. (1851-1938). Henry Ward Ranger bequest.

Oil, Margery and Little Edmund, by Edmund C. Tarbell, N. A. (1862-1938). Henry Ward Ranger bequest.

Accepted for the National Portrait Gallery

Oil, George Washington Carver, by Betsy Graves Reyneau. Gift of the George Washington Carver Memorial Committee.

Accepted for the Smithsonian Institution

Water color on silk, Tiger, by Ih Dang (Mr. Kim, Eun Ho). Gift of the artist through John R. Hodge, Lieutenant General, United States Army.

Oils, 44 portraits of World War II heroes, by Joseph Cummings Chase. Gift of the artist. Assigned to the Department of History February 17, 1949.

DEPOSITS

Oil, Portrait of Spencer Fullerton Baird, the second Secretary of the Smithsonian Institution, by Henry Ulke (1821-1910). Purchased by the Smithsonian Institution and deposited August 6, 1948.

Bronze, African Elephant Scenting Danger, by Eli Harvey. Accepted as a gift of the sculptor and deposited by the Smithsonian Institution December 9, 1948.

THE CATHERINE WALDEN MYER FUND

Two miniatures, water color on ivory, were acquired from the fund established through the bequest of the late Catherine Walden Myer, as follows:

68. Henry A. Coit, by John Wood Dodge (1807-1893); from Edmund Bury, Philadelphia, Pa.

69. Ebenezer Martin of Martin's Ferry, Ohio, attributed to Henry Inman (1801-1846); from Miss Alice L. Wood, Blowing Rock, N. C.

LOANS ACCEPTED

Three Nymphenburg figurines were lent by Miss Cornelia Morrison, Newton, N. C., on February 7, 1949.

One miniature, water color on ivory, Portrait of Elsie Clough Street, by Gerald S. Haywood, was lent by Mrs. James Walter Rickey on February 15, 1949.

One oil painting, Portrait of Sr. Benito Juarez, by Tom Lea, was lent by the State Department on February 18, 1949.

Two oil paintings, Portrait of the Hon. Grizel Ross, by William Hogarth, and Portrait of Gen. Sir Charles Ross, by George Romney, and one miniature, water color on ivory, Portrait of the 8th Baronet Sir Charles Ross, by E. C. Thomson, were lent by Lady Ross of Balnagown Castle, Ross-shire, Scotland, on April 4, 1949.

WITHDRAWALS BY OWNERS

A bronze bust of Abraham Lincoln, by Augustus Saint-Gaudens, lent by Mrs. Augustus Saint-Gaudens in 1912, was withdrawn August 24, 1948, at the request of Homer Saint-Gaudens.

Two oil paintings, Shoshone Falls, Idaho, and Spectres of the North, by Thomas Moran, lent by Miss Ruth B. Moran in 1923, were withdrawn October 6, 1948, by the executor of Miss Moran's estate.

An oil painting, The Nativity, by an unknown artist, lent by St. Paul's Church in 1945, was withdrawn February 9, 1949, by the owner.

Nine miniatures painted by Mrs. E. D. Sparrow when she was Mary Hall, lent by the artist in 1929, were withdrawn April 25, 1949.

LOANS TO OTHER MUSEUMS AND ORGANIZATIONS

The original design for the painting in the Capitol Building, Westward the Course of Empire Takes Its Way, by Emanuel Leutze, was lent to the Akron Art Institute August 17, 1948, to be included in the Freedom Train Exhibition at Akron, Ohio. (Returned October 5, 1948.)

An oil painting, Portrait of Admiral William Snowden Sims, by Irving Wiles, was lent to the Metropolitan Museum of Art for an exhibition held in conjunction with the United States Navy, entitled "Your Navy, Its Contribution to America from Colonial Days to World Leadership," held from October 25 through December 5, 1948. (Returned January 13, 1949.)

An oil painting, Sunset, Navarro Ridge, California Coast, by Ralph Blakelock, was lent to The Brooklyn Museum, Brooklyn, N. Y., for an exhibition "The Coast and the Sea, A Survey of American Marine

Painting," held from November 19, 1948, to January 16, 1949. (Returned February 3, 1949.)

Two oil paintings, Portrait of George Washington, attributed to William Winstanley, after Gilbert Stuart, and The Signing of the Treaty of Ghent, Christmas Eve, 1814, by Sir Amédée Forestier, were lent March 22, 1949, to the Department of State to be hung in the office of the Secretary of State.

An oil painting, Portrait of Andrew Jackson, by Rembrandt Peale, was lent to the Committee on Un-American Activities March 25, 1949, to be hung in its committee room for an indefinite period.

THE HENRY WARD RANGER FUND

Since it is a provision of the Ranger bequest that the paintings purchased by the Council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest, and assigned to American art institutions, may be claimed by the National Collection of Fine Arts during the 5-year period beginning 10 years after the death of the artist represented, seven paintings were recalled for action of the Smithsonian Art Commission at its meeting December 7, 1948.

Two paintings, listed earlier in this report, were accepted by the Commission to become permanent accessions.

The following five paintings were returned to the institutions to which they were originally assigned, or reassigned, by the National Academy of Design as indicated.

No. 3. Grey Day, by W. Granville-Smith, N. A. (1870-1938), assigned to the National Gallery of Art (now National Collection of Fine Arts).

No. 48. The Prodigal Son, by Horatio N. Walker, N. A. (1858-1938), assigned to the Albright Art Gallery, Buffalo Fine Arts Academy, Delaware Park, Buffalo, N. Y.

No. 56. Southaven Mill, by W. Granville-Smith, N. A., assigned to the Toledo Museum of Art, Toledo, Ohio.

No. 63. Cyprispedia, by Sergeant Kendall, N. A. (1869-1938), assigned to the California Palace of the Legion of Honor, San Francisco, Calif.

No. 90. Summer, by W. L. Lathrop, N. A. (1859-1938), reassigned by the National Academy of Design to the Mary Washington College, University of Virginia, Fredericksburg, Va.

The following paintings, purchased by the Council of the National Academy of Design in 1948, were assigned as follows:

No. 120. Sunlight on the Waterfront, by Ferdinand E. Warren, N. A. (1899-), to the Currier Gallery of Art, Manchester, N. H., May 13, 1949.

No. 121. Village Green, by John Pike, N. A. (1911-), to the Washington State Historical Society, Tacoma, Wash., March 15, 1949.

No. 124. Lobstermen, by Andrew Winter, N. A. (1893-), to the Mint Museum of Art, Inc., Charlotte, N. C., June 1, 1949.

THE NATIONAL COLLECTION OF FINE ARTS REFERENCE LIBRARY

A total of 347 publications (219 volumes and 128 pamphlets) were accessioned, bringing the total National Collection of Fine Arts library accessions to 11,364.

The most noteworthy gift this year was that of the Ferdinand Perret Research Library of the Arts and their Affiliated Sciences, from Ferdinand Perret of Los Angeles, Calif. This library, a series of uniform portfolios, containing mounted reproductions of paintings and art objects, represents many years of work on the part of Mr. Perret. The volumes on painters and sculptors are arranged by schools and alphabetically according to the names of the artists.

PRESERVATION

In addition to much necessary repair and renovation to the permanent collections, portraits were cleaned, restored, and revarnished for the following departments: State Department—Secretaries of State John Hay and Elihu Root, by unknown artists. Marine Corps, Department of the Navy—Generals Franklin Wharton and George Barnett, by L. H. Gebhard; George Elliott, by Richard N. Brooke; John A. Lejeune, by S. B. Baker; Archibald Henderson, by R. Le Grande Johnston, and John H. Russell, by Bjorn Egeli. United States Air Force—a minor correction was made to the uniform in the portrait of Brig. Gen. R. E. Ramey.

The portrait of Alvin C. York, by Joseph Cummings Chase, was cleaned for the Department of History, United States National Museum.

INFORMATION SERVICE

The requests for information of 1,422 visitors received special attention, as did many similar requests by mail and phone; 332 art works were submitted for identification.

The Director and Mr. Gardner, curator of ceramics, gave lectures on art topics during the year to a number of groups, including the District of Columbia Chapter of the American Association of University Women, the art section of the Twentieth Century Club, a group of art students from the Washington Missionary College, Takoma Park, Md., the American Association of Music and Fine Arts, and the District Chapter of the National League of American Pen Women. They also served as judges or as members of juries of selection and award for a number of exhibitions held in Washington.

Permission was given to four persons to copy art works in the collection.

SPECIAL EXHIBITIONS

In addition to the regularly scheduled temporary exhibitions listed below, the Community Chests of America and the Louisiana State Society of Washington held special showings of paintings of timely interest in the lobby of the Natural History Building for short periods. The Federal Security Agency was assisted in a Memorial Day exhibition of paintings by Leslie E. Lane under the sponsorship of the American Legion.

August 7 through 29, 1948.—Exhibition of 94 portraits of Soldiers of Two World Wars, by Joseph Cummings Chase.

November 7 through 28, 1948.—The Eleventh Metropolitan State Art Contest, held under the auspices of the District of Columbia Chapter, American Artist's Professional League assisted by the Entre Nous Club, consisting of 327 specimens of paintings, sculpture, prints, ceramics, and metalcraft. A catalog was privately printed.

January 12 through 30, 1949.—Exhibition of Polish Manual Arts, held under the patronage of His Excellency Jozef Winiewicz, Ambassador of Poland to the United States, and the auspices of The American Federation of Arts, consisting of 131 pieces of tapestries, paintings on glass, and folk sculpture. A catalog was privately printed.

February 6 through 27, 1949.—The Sixteenth Annual Exhibition of The Miniature Painters, Sculptors and Gravers Society of Washington, D. C., consisting of 155 examples. A catalog was privately printed.

April 7 through 27, 1949.—The Twenty-fifth Annual Hoosier Salon held under the sponsorship of the Indiana State Society of Washington, consisting of 196 paintings, prints, and sculpture. A catalog was privately printed.

May 8 through 30, 1949.—The Fifty-third Annual Exhibition of the Washington Water Color Club, consisting of 135 paintings and prints. A catalog was privately printed.

Respectfully submitted.

THOMAS M. BEGGS, *Director.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the twenty-ninth annual report on the Freer Gallery of Art for the year ended June 30, 1949.

THE COLLECTIONS

Additions to the collections by purchase were as follows:

BRONZE

- 48.24. Chinese, Chou dynasty (1122-256 B. C., late). A quadruped; linear designs in countersunk relief; smooth gray-green patina with encrustations of green; cracked in places, forelegs repaired. 0.118 x 0.204.
- 48.25. Chinese, Chou dynasty (1122-256 B. C., late). A garment hook inlaid with silver and gold. 0.227 x 0.025.
- 48.26. Chinese, Chou dynasty (1122-256 B. C., late). A garment hook inlaid with turquoise and gold; underside plated with silver. 0.212 x 0.017.
- 49.4. Chinese, Northern Wei dynasty (A. D. 386-535). A figure standing on a lotus pedestal in a six-lobed dish; silvery-gray patina encrusted with malachite, azurite, and dirt adhesions; dish supported on three lugs. 0.243 x 0.215.
- 49.5. Chinese, Shang dynasty (1766-1122 B. C., late). A covered ceremonial vessel of the type *hu* decorated with casting in relief; smooth gray-green patina. (Illustrated.) 0.176 x 0.115.
- 49.6. Chinese, Chou dynasty (1122-256 B. C., late). A garment hook with interlaced dragon design inlaid in gold on background of silver dots. 0.123 x 0.060.

GLASS

- 48.14. Syrian (late 13th century). A beaker with fluted body and flaring lip; honey-colored glass decorated with colored enamels and gold. 0.295 x 0.172.

GOLD

- 48.25. Syrian or Egyptian (10th-11th century). A hinged armlet of hollow gold decorated with fine filigree work, *kufic* inscriptions, and settings for five stones (now missing). Width: 0.129.

JADE

- 48.12. Chinese, Chou dynasty (1122-256 B. C., late). A flat ring of the type *yüan* carved with small whorl marks in low relief; pale greenish-gray nephrite, partly deteriorated. Diameter: 0.123.
- 48.13. Chinese, Chou dynasty (1122-256 B. C., late). A garment hook decorated with incised linear patterns and carving in low relief; hook in form of animal head repaired; pale nephrite almost all deteriorated to cream color. 0.131 x 0.008.

LACQUER

- 49.1. Chinese, Chou dynasty (1122–256 B. C., late). A shallow, oval ceremonial cup on a stand, wood covered with black lacquer with red designs outside; black on red inside. 0.235 x 0.179.

MANUSCRIPT

- 48.9. Arabic, Egypt (14th–15th century). A leaf from a Koran; recto: illuminated with gold on blue and gold grounds, three white *kūfic* inscriptions; verso: text in black *naskhī* in a decorative border. 0.332 x 0.245.
- 49.2. Persian (16th century). A text of the *Gulistān* by Sa'di written by Rajab b. Khair al-din . . . 153 folios, illuminated *sarlawh*, two Turkish miniatures; text in black *nasta'liq* with captions in blue, red, and gold; contemporary binding, new back and edges. 0.191 x 0.118.
- 49.3. Persian (15th century). A text of Mihr and Mushtari by 'Assār written by Shaikh Murshid al-Kātib in Shīrāz, A. H. 882 (A. D. 1477); 223 folios, illuminated *'unvān*, three miniatures; text in black *nasta'liq*, chapter headings in gold on decorated ground; contemporary binding. 0.201 x 0.122.

MARBLE

- 48.23. Chinese, Shang dynasty (1766–1122 B. C., late). An ornamental carving in high and low relief; slightly decomposed. 0.085 x 0.050.

PAINTING

- 48.8. Indian, Akbar period (1556–1605), Mughal. Noah's Ark; painted in colors and gold. 0.281 x 0.156.
- 48.10. Chinese, Sung dynasty (960–1279, early). Portrait of Wang Huan; ink and color on silk; one inscription and two seals on painting. 0.393 x 0.317.
- 48.11. Chinese, Sung dynasty (960–1279, early). Portrait of Fēng P'ing; ink and color on silk; one inscription and three seals on painting. (Illustrated.) 0.399 x 0.327.
- 48.15. Persian, Īl-Khān period (14th century). Mongol. "Gushtāsp killing the Dragon"; painted in colors and gold on paper; proto-*nasta'liq* script, black for text and black and red for captions, fills upper three-quarters of page. 0.368 x 0.300.
- 48.17. Turkish (mid-16th century). Chinoiserie: a lion, a *ch'i-lin* and a dragon amid floral sprays; ink, gold and slight color on paper. 0.175 x 0.285.
- 48.18. Persian, Timurid period (first half, 15th century), Shīrāz school. Timur's entry into Samarquand; leaf from a *Zafar-nāma* painted in colors and gold; text in black *naskhī*, title in red. 0.259 x 0.132.
- 48.19A. Indian (early 17th century) Mughal, school of Jahāngīr. A vulture, by Manṣūr, in colors on paper on the recto of a leaf from an imperial album; verses and signature in *nasta'liq* amid floral rinceaux, wide border of gold foliage. (Illustrated.) 0.163 x 0.102.
- 48.19B. Indian (early 17th century) Mughal, school of Jahāngīr. Jahāngīr standing on a globe shoots an arrow at the impaled head of his enemy Malik 'Anbar, by Abu'l-Hasan (Nādir al-zamān); verso of the above leaf from an imperial album; gold and colors on paper, *nasta'liq* script. 0.380 x 0.260.
- 48.20. Indian (early 17th century) Mughal, school of Jahāngīr. Portrait of I'timād al-dawla by Bālcchand; ink and colors on paper; borders with

verses in black *nasta'liq* and gold and polychrome floral designs; verso: poems and floral decoration. 0.381 x 0.259.

- 48.21. Indian (early 17th century), Mughal, school of Jahāngīr. A bee-eater, by Farrukh Beg, painted in colors on the verso of a leaf from an imperial album; verses in *nasta'liq* and decorative borders. On the recto of this leaf, a painting of the same period and school shows a bowman, musician, and dervish, by Bichitr, in gold and colors, also with verses in *nasta'liq* and decorative borders. 0.384 x 0.263.
- 48.22. Chinese, Ming dynasty (14th century). Landscape in the style of Wang Meng (d. 1385); ink on gray paper; two inscriptions and eight seals on painting. 0.855 x 0.397.
- 48.28. Indian (early 17th century), Mughal, school of Jahāngīr. Portrait of Jahāngīr, by Abū'l-Hasan (Nādir al-zamān); in colors and gold on paper; signature and three inscriptions. 0.388 x 0.257.

STONE SCULPTURE

- 48.16. Persian (dated A. H. 549, A. D. 1154-1155). A building inscription by Aḥmad b. Muḥammad b. Aḥmad (Asid or Usaid), carved in a slab of alabasterlike stone in the form of a *mihṛāb*; covered with *kūfī* and *naskhī* inscriptions. (Illustrated.) 0.925 x 0.676.

The work of the staff members has been devoted to the study of new accessions, of objects submitted for purchase, and to general research within the collections of Chinese, Japanese, Persian, Arabic, and Indian materials. Reports, oral or written, were made upon 2,563 objects and 372 photographs of objects submitted for examination; and 369 Oriental language inscriptions were translated. Docent service and other lectures given by staff members are listed below.

REPAIRS TO THE COLLECTIONS

A total of 27 objects were cleaned, resurfaced, remounted, or repaired as follows:

American paintings cleaned and resurfaced.....	14
Chinese paintings remounted.....	3
Chinese pottery repaired.....	2
Japanese paintings remounted.....	7
Japanese pottery repaired.....	1

The repair and restoration of the walls of the Peacock Room by James McNeill Whistler, mentioned in last year's report, were completed on September 27 and the room was reopened to the public on October 4. It was closed again the first of the year and on January 7, 1949, the work of repairing and restoring the ceiling was begun. This involves taking down the ceiling, lining each panel with canvas, treating it with moisture-proof wax, and mounting it on a heavy plywood backing. The painting on the wood is then cleaned with the utmost care, later repaint is removed, gilding and paint are renewed in areas from which they were gone altogether and the whole thing is resurfaced. The work is still in progress on a part-time basis by John

A. and Richard M. Finlayson of the Museum of Fine Arts, Boston, and the structural work is being done by the Gallery cabinet shop.

CHANGES IN EXHIBITIONS

Changes in exhibitions totaled 53, as follows:

American paintings-----	25
Peacock Room (temporarily closed)-----	1
Chinese gilt bronze-----	2
Chinese paintings-----	4
Chinese pottery-----	5
Japanese paintings-----	16

This unusually small number of exhibition changes is accounted for by the lack of a painter in the Gallery.

LIBRARY

During the year the following work was accomplished in the library:

Accessions, including books, pamphlets, charts, rubbings, and study photographs, 753; cataloging of all kinds, including cards typed and filed, 4,448; binding, repairing, and mounting, 693.

An inventory of the library holdings was completed, and statistics now show the number of books, pamphlets, and other items, rather than the number of titles. The periodicals, including museum publications, were inventoried, revised, and alphabetically shelved in the periodical room.

PUBLICATIONS

The following new edition of a former title was published: Annotated Outline of the History of Japanese Art, new issue, March 1949.

Occasional Papers, vol. 1, No. 2: Paintings, Pastels, Drawings, Prints, and Copper Plates by and Attributed to American and European Artists, together with a List of Original Whistleriana, in the Freer Gallery of Art, by Burns A. Stubbs, was published in August 1948.

REPRODUCTIONS

During the year the photographic laboratory made 4,332 prints, 713 glass negatives, 607 black-and-white slides and 269 color slides.

ATTENDANCE

The Gallery was open to the public from 9:00 to 4:30 every day except Christmas Day. The total number of visitors to come in the main entrance was 74,846. The weekday total was 59,595, and 15,096 visitors came on Sundays. The averages were: Weekdays, 198; Sundays, 290. The highest monthly attendance was in August with 8,300 and the lowest was in December with 2,622.

There were 1,724 visitors to the main office during the year; the purpose of their visits was as follows:

For general information.....	787
To see staff members.....	91
To read in the library.....	217
To make sketches and tracings from library books.....	9
To see buildings and installations.....	24
To make photographs in court and sketches in exhibition galleries...	74
To examine, borrow, or purchase photographs and slides.....	333
To submit objects for examination.....	378
To see objects in storage.....	237
Washington Mss.....	29
Far Eastern paintings and textiles.....	48
Near Eastern paintings and manuscripts.....	21
Tibetan paintings.....	3
American paintings.....	20
Whistler prints.....	1
Oriental pottery, jade, bronze, lacquer, and bamboo...	96
All sculpture.....	8
Syrian and other glass.....	11

SPECIAL VISITORS

Two scholars made extended study visits to the Gallery during the year, as follows:

- Nov. 22, 1948-Jan. 26, 1949.. Mr. Shih-hsiang Wang, Curator of Paintings in the Palace Museum in Peiping, studied the construction and operation of the building as a whole and made a detailed study of the collection of Chinese paintings.
- Feb. 7-Mar. 4, 1949..... Mr. Won-yong Kim, of the National Museum of Korea, studied the Gallery and the Far Eastern collections.

DOCENT SERVICE AND OTHER STAFF ACTIVITIES

By request 16 groups met in the exhibition galleries for instruction by staff members. Total attendance was 358.

On invitation the following lectures were given outside the Gallery by staff members:

1948

- Oct. 20..... Mr. Pope lectured at the Denver Art Museum, Denver, Colo., on (1) "Pre-historic Pottery and Unglazed Wares of Shang, Chou and Han." (Illustrated.) Attendance, 150.
- Oct. 21..... Mr. Pope lectured at Denver Art Museum, Denver, Colo., on (2) "Beginnings of Glaze and of Porcelain and their Development through the Ming Dynasty." (Illustrated.) Attendance, 150.

1948

- Oct. 22----- Mr. Pope lectured at Denver Art Museum, Denver, Colo., on (3) "The Development of European Interest in Chinese Porcelain and the Final Refinements of Manufacture at Ching-tê Chên in the Ch'ing Dynasty." (Illustrated.) Attendance, 150.
- Oct. 27----- Mr. Pope lectured at Nelson Gallery of Art, Kansas City, Mo., on No. 3 (See Oct. 22 above). (Illustrated.) Attendance, 110.
- Oct. 28----- Dr. Ettinghausen lectured before the Alexandria Woman's Club, Alexandria, Va., on "Culture of the Near East." (Illustrated.) Attendance, 80.
- Oct. 30----- Mr. Pope lectured at City Art Museum, St. Louis, Mo., on No. 3 (see Oct. 22 above). (Illustrated.) Attendance, 175.
- Nov. 4----- Mr. Pope lectured at Kellogg Auditorium, Ann Arbor, Mich., on No. 3 (see Oct. 22 above). (Illustrated.) Attendance, 175.
- Nov. 29----- Mr. Pope lectured at Bradford Junior College, Bradford, Mass., on "Introduction of Chinese Ceramics to Europe" to members of the faculty. (Illustrated.) Attendance, 25.

1949

- Jan. 6----- Dr. Ettinghausen lectured at Arts Club of Washington, Washington, D. C., on "Biblical Subjects Seen through Persian Eyes." (Illustrated.) Attendance, 80.
- Jan. 27----- Dr. Ettinghausen lectured at the Annual Meeting of the College Art Association, Oriental Section, in Baltimore, Md., on "A Near Eastern Motif in Far Eastern Garb." (Illustrated.) Attendance, 60.
- Feb. 12----- Mr. Acker lectured at the Zen Institute of America, 124 East 65th Street, New York, N. Y., on "The Hōryūji Wall Paintings Recently Destroyed by Fire." (Illustrated by slides belonging to the Institute.) Attendance, 30.
- Feb. 14----- Dr. Ettinghausen lectured at the Oriental Club of Princeton University, Princeton, N. J., on "Symbols and Religious Themes in Moslem Art." (Illustrated.) Attendance, 75.

1949

Apr. 6----- Mr. Pope lectured at the Annual Meeting of the Far Eastern Association (Section on China: Art and Archaeology) on "Technical Notes on Shang White Pottery." (Illustrated.) Attendance, 40.

Members of the staff traveled outside of Washington for professional purposes as follows:

1948

July 6-7----- Dr. Ettinghausen in Cincinnati, examined objects at Cincinnati Art Museum.

Aug. 25-30----- Mr. Stubbs in Chicago, attended convention of the Photographers Association of America.

1949

Jan. 19-23----- Mr. Pope in New York, examined objects belonging to museums and dealers.

Jan. 27----- Mr. Wenley, Mr. Pope, Dr. Ettinghausen, and Mr. Acker in Baltimore, attended the Oriental Section of the Annual Meeting of the College Art Association. Mr. Pope served as chairman of this section and Dr. Ettinghausen was among those reading papers.

Jan. 28----- Mr. Pope and Dr. Ettinghausen in Baltimore for second day of above meeting.

Feb. 13-18----- Mr. Wenley in New York, examined objects belonging to museums and dealers.

Feb. 15-19----- Dr. Ettinghausen in New York, examined objects belonging to museums and dealers.

Mar. 31-Apr. 1----- Mr. Wenley in Ann Arbor, conferred with officials of the University of Michigan in regard to cooperation with the University in its Oriental program.

Apr. 5-8----- Mr. Pope in New Haven, attended the joint Annual Meeting of the American Oriental Society and the Far Eastern Association; read a paper at one session of the FEA meeting. In Meriden, Conn., visited the Meriden Gravure Company to observe methods of collotype and offset printing. In New York, examined objects belonging to dealers.

May 20-21----- Mr. Pope in New York, attended preliminary dinner and organization meetings of the Far Eastern Ceramic Group and was elected first president of the Group. Examined objects belonging to museums, private collectors, and dealers.

June 20----- Dr. Ettinghausen in Ann Arbor, Mich., began teaching in University of Michigan summer session; one course on "Persian Art," one course on "Persian Painting."

HONORARY DUTIES

During the year, members of the staff undertook honorary duties outside the Institution as follows:

Mr. Wenley: Appointed to the committee of expert examiners for the Smithsonian Institution by the Civil Service Commission.

Appointed to serve on the nominating committee of the Far Eastern Association.

Appointed as Honorary Curator of Oriental Art, Department of Fine Arts, University of Michigan.

Appointed to serve as a member of the visiting committee of Dumbarton Oaks Research Library and Collection.

Mr. Pope: Elected President of the Far Eastern Ceramic Group.

Respectfully submitted.

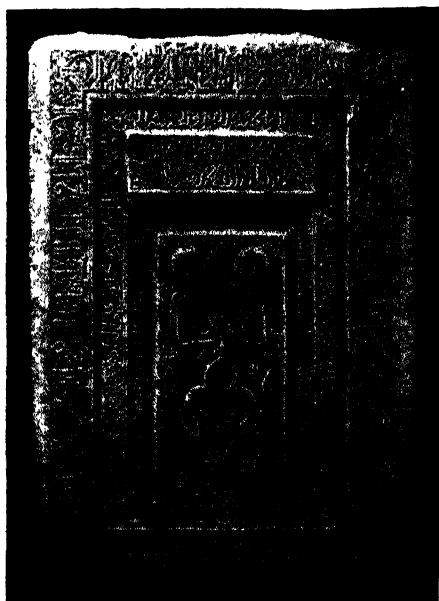
A. G. WENLEY, *Director.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.



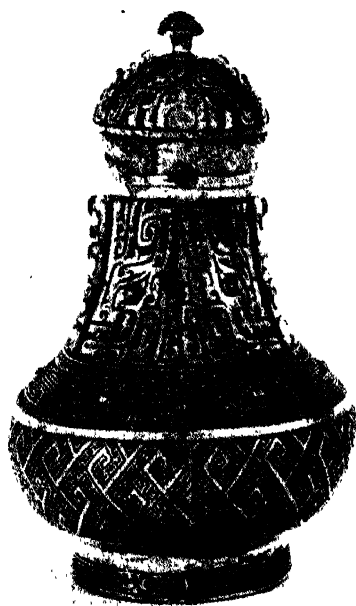
48.19A



48.16



48.11



49.5

RECENT ADDITIONS TO THE COLLECTION OF THE FREER GALLERY OF ART

APPENDIX 5

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following Report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1949, conducted in accordance with the Act of Congress of June 27, 1944, which provides “* * * for continuing ethnological researches among the American Indians and the natives of Hawaii and the excavation and preservation of archeologic remains. * * *”

SYSTEMATIC RESEARCHES

At the end of December Dr. M. W. Stirling, Director of the Bureau, left to continue the cooperative program of archeological work in Panamá of the National Geographic Society and the Smithsonian Institution. Excavations were conducted at Utivé in the province of Panamá, at Barriles and Palo Santo in the province of Chiriquí, and at three sites midway between Santiago and Soná in the province of Veraguas. At Utivé and Barriles heretofore undescribed ceramic cultures were encountered, while at the other sites much new information was obtained on the classic Chiriquí and Veraguas cultures. The expedition received splendid cooperation from Maj. Gen. Willis Hale, commanding general of the air forces of the Caribbean area, who, in addition to other assistance, allowed the use of two helicopters for reconnaissance work in the Utivé-Chepo area. Dr. Stirling returned to Washington with the Panamanian collections in the middle of May.

Dr. Frank H. H. Roberts, Jr., Associate Director of the Bureau and Director of the River Basin Surveys, devoted the greater part of his time during the fiscal year to the direction and administration of the River Basin Surveys. On November 4 and 5, Dr. Roberts attended the meetings of the American Philosophical Society at Philadelphia where he presented a paper on the River Basin Surveys program. From November 22 to 30, Dr. Roberts was at Lincoln, Nebr., inspecting the field headquarters for the Missouri Basin project. While at Lincoln he also took part in the Sixth Conference for Plains Archeology and presided over one of the symposia. During the year he also served as a member of the executive committee for the Divi-

sion of Anthropology and Psychology, National Research Council. Dr. Roberts' report of the work of the River Basin Surveys during the fiscal year appears in another section of this report.

Dr. John P. Harrington, ethnologist, continued the revision of his grammar of the Maya language. Study of sources and the vast literature on the subject shows that there were 10 linguistic stocks in southern México and Central America that had Maya-style hieroglyphic writing. The work also included revision of a previous paper on Maya hieroglyphs.

A study incident to this Maya work was the determination of the origin of the word "Maya." This word appears first in the letter written by Bartholomew Columbus in 1506 telling of the fourth voyage of Columbus. The letter employs the spelling "Mayam" which is clearly derived from the native Maya name for Yucatán, Mayab.

During the winter a paper was prepared on the names "Tiwa" and "Tewa," designations of two languages in New Mexico. Early in the spring Dr. Harrington prepared a series of six maps of America showing the meanings of State, province, and country names.

On April 14 Dr. Harrington left Washington for Old Town, Maine, to pursue ethnological and linguistic studies on the Abnaki Indians. He was engaged in this project at the end of the fiscal year.

Dr. Henry B. Collins left Washington in June for the Arctic, having been invited by the Canadian Government to conduct archeological excavations with the assistance of Colin Thacker of the National Museum of Canada at Frobisher Bay on Baffin Island, where Charles Francis Hall in 1868 had reported ancient Eskimo house ruins and where a large group of Eskimo now live. The Eskimo ruins were found—buried remains of semisubterranean houses made of stones, whale bones, and turf. Excavation showed that the site had been occupied successively by Eskimo of both the prehistoric Dorset and Thule cultures. Comparison with other prehistoric Eskimo sites indicated that the Dorset phase represented is one of the earliest of that culture known. The Thule phase, which followed the Dorset, is likewise early, showing close affinities with northern Alaska, its place of origin. In addition to the archeological work, measurements were obtained and photographs taken of 80 adult Eskimo—40 males and 40 females—at Frobisher Bay. This was the first anthropometric study to be made of the present-day Baffin Island Eskimo.

In Washington Dr. Collins continued as anthropological adviser for the *Encyclopaedia Arctica*, which Dr. Vilhjalmur Stefansson is preparing for the Office of Naval Research. Dr. Collins' term of office as Chairman of the Board of Governors of the Arctic Institute of North America terminated at the end of the calendar year 1948, but he continued as chairman of the directing committee for the Institute's

Bibliography of Arctic Literature and Roster of Arctic Specialists. In continuation of the archeological program begun in 1948 Dr. Collins left Washington in May to conduct excavations at Resolute Bay, Cornwallis Island, N. W. T., under the joint auspices of the Smithsonian Institution and the National Museum of Canada.

From July 1 to September 10 Dr. Fenton was engaged in field work among the Seneca Indians of western New York on a grant from the Viking Fund of New York City. Working at Quaker Bridge on Allegany Indian Reservation, he obtained a life history of an aged Seneca named Chauncey Johnny John with whom Dr. Fenton has worked since 1933. Especially fine materials were collected on social organization, kinship, and age grades. Twelve reels of recordings were made which included the entire ritual of the Seneca Dark Dance, the opening address and several long prayers belonging to the Green Corn Festival, the entire Women's Rite of Thanksgiving to the cultivated crops, and an origin legend for the False-face Society in Seneca and in English.

The Fourth Conference on Iroquois Research, under the direction of Dr. Fenton, met at Red House, N. Y., October 8-10, to review outstanding accomplishments in Iroquoian studies in the fields of linguistics, ethnology, and archeology. The Proceedings of the Conference, edited by Dr. Fenton, were issued in mimeograph form by the Smithsonian Institution.

The project of collecting materials for a political history of the Six Nations was reported in a general paper to the American Philosophical Society on November 4. The same research led to examining the Kirkland Papers in Hamilton College Library, and on December 1 Dr. Fenton addressed the College on its founder: "Samuel Kirkland: Observer, Negotiator, and Educator." A lecture was given to the Anthropology Club of Syracuse University, and manuscripts were examined in local libraries. Work continued in the manuscript collections of the New York Historical Society and at the New York Public Library. The Massachusetts Archives in the State House, the Essex Institute in Salem, and the Peabody Museum of Salem were visited in January. Three reels of the Pickering Papers were completed and filed. Arrangements were made with Dr. C. M. Barbeau of the National Museum of Canada for obtaining microfilm of documents in Canadian libraries for the American Philosophical Society Library.

During the year Dr. Fenton served as a member of the Language Panel of the United States National Commission for UNESCO; he represented the Smithsonian at meetings of the Policy Board of the United States National Indian Institute, and in subsequent conferences at the State Department toward a Second Inter-American Confer-

ence on *Indian Life*, for which he prepared a paper. He served as President of the Anthropological Society of Washington.

Dr. Fenton published several papers on anthropological subjects in various journals during the year.

The research activities of Dr. Gordon R. Willey, anthropologist, during the year were confined principally to study of data and materials previously obtained in the field. They included the final preparation of a monograph, "Archeology of the Florida Gulf Coast," a culmination of studies begun by the Bureau of American Ethnology as early as 1923, with Dr. Willey engaged on the project since 1940. The war and other duties interrupted the completion of the manuscript, but it is now in process of publication by the Smithsonian. Eight other manuscripts by Dr. Willey are in press or awaiting publication, and four additional manuscripts are in preparation: "Ancon-Supe: Formative Period Sites of Central Perú" (with J. M. Corbett and L. M. O'Neale); "Huari, an Important Site in the Central Peruvian Highlands" (with D. Collier and J. H. Rowe); "Prehistoric Settlement Patterns in the Virú Valley, Perú," and "Archaeological Explorations in the Parita Zone, Panamá."

Dr. Willey served in a consultative capacity for the period of final editing of volumes 5 and 6 of the *Handbook of South American Indians* (Bureau Bulletin 143) and also assisted with certain administrative matters concerned with the Smithsonian River Basin Surveys.

Dr. Willey participated in a series of round-table discussions under the leadership of Dr. A. L. Kroeber during the months October through February. These meetings, held at Columbia University, New York, were concerned with general discussions of anthropological method and theory. Throughout the year he served as assistant editor for the *Handbook of Latin American Studies* of the Library of Congress Hispanic Foundation. He also served as assistant editor of the journal *American Antiquity*, with reference to the South American area.

From March through May Dr. Willey served as Smithsonian representative at several committee meetings of the State Department Committee for Scientific and Cultural Cooperation, and at an open meeting of the Caribbean Commission.

SPECIAL RESEARCHES

Miss Frances Densmore, collaborator of the Bureau, submitted to the Bureau a manuscript entitled "Musical Customs of the Indians of the Paraná Delta and La Plata Littoral and the Gran Chaco."

INSTITUTE OF SOCIAL ANTHROPOLOGY

The Institute of Social Anthropology was created in 1943 as an autonomous unit of the Bureau of American Ethnology to carry out

cooperative training in anthropological teaching and research with the other American republics. During the past year it was financed by transfers from the Department of State totaling \$97,900 from the appropriation "Cooperation with the American Republics, 1949." Long-range planning for the Institute became increasingly difficult during the year because of threatened budget reductions for the fiscal year of 1950. Otherwise, the Institute continued to function much as in previous years, and good work was done by all staff members. Principal activities were as follow:

Washington office.—Dr. George M. Foster, Director of the Institute of Social Anthropology, made a 3-weeks trip to Spain in November 1948 to investigate the possibility of ethnographical field work in that country, with a view to throwing additional light on the development of the contemporary cultures of Hispanic America. In March 1949 Dr. Foster made a second trip to Spain, serving as Smithsonian Institution delegate at the centennial celebration of the Royal Academy of Natural, Exact, and Physical Sciences of Madrid. Dr. Gordon R. Willey assumed direction of the Institute of Social Anthropology during Dr. Foster's absence.

Upon the recommendation of the Director a grant-in-aid was extended by the Department of State to bring Dr. Luis Duque Gómez, Director of the Instituto Etnológico y Servicio de Arqueología of Bogotá, Colombia, to the United States for a 3-months period, October 1948 to January 1949. An itinerary was arranged by Dr. Foster whereby Dr. Duque was able to visit the larger universities and anthropological centers in the United States both in the East and in the West. Also upon the recommendation of the Director, a like invitation was extended to Dr. José Cruzent, Director of the Museo de Ciencias Naturales in Caracas, Venezuela. Dr. Cruzent is expected to arrive in the United States in August 1949.

Brazil.—Drs. Donald Pierson, sociologist, and Kalervo Oberg, social anthropologist, continued to give courses at the Escola Livre de Sociologia e Política in São Paulo, Brazil. Dr. Pierson, assisted by students from the school, completed field work in the *caboclo* community of "A Vila" near São Paulo, and completed a manuscript describing this work. Dr. Pierson also served as official observer of the United States Government at the UNESCO Conference held in Montevideo, Uruguay, September 6-10, 1948, to consider ways and means of stimulating the development of science in Latin America. He was brought to the United States at the end of June 1949, for consultation on future plans for work in Brazil. Dr. Oberg spent July and part of August 1948 in field work among the Indians of the headwaters of the Xingú River. In June 1949 he left on a 3-months trip to the Paressí and Nambiquara groups, northwest of Cuiabá in

Mato Grosso. On both of these trips he was accompanied by students from the Escola Livre.

Colombia.—Dr. John H. Rowe returned to the United States from Popayán, Colombia, in September to accept a permanent position at the University of California. Dr. Raymond E. Crist, professor of geography at the University of Maryland, was employed in February 1949 on a temporary basis to replace Dr. Rowe. In the short time Dr. Crist has been in Popayán he has given courses and lectures in the Universidad del Cauca, dealing with Iberian culture and its dissemination in the New World, and with geographic methods and theories. He has made several short field trips to small communities near Popayán, and has been host to the American Ambassador, Willard L. Beaulac, who, with his private party, flew from Bogotá for the express purpose of becoming acquainted with the work of the Institute in Popayán.

México.—Dr. Isabel Kelly, social anthropologist, continued to represent the Institute at the Escuela Nacional de Antropología in Mexico City, giving anthropology courses and guiding independent research of students. A part of the spring of 1949 again was spent in the Totonac area, where final field notes on this group were taken, preparatory to writing a monograph describing the results of three seasons of work. Dr. Stanley Newman, linguist, resigned from the Institute in February 1949, to accept a position at the University of New Mexico. Up to this time he continued his teaching schedule at the Escuela. His research included investigations of the Otomi and Nahuatl Indian languages, and participation in the literacy campaign of the Mexican Government. A significant paper on the Otomi language was completed, and a major monograph on Nahuatl was undertaken.

Perú.—Dr. Allan Holmberg resigned from the Institute in August 1948 to accept a permanent position at Cornell University. He was immediately replaced by Dr. George Kubler, of Yale University, who arrived in Lima early in September. Dr. Kubler continued teaching projects in the Instituto de Estudios Etnológicos, and also gave a course in the University of San Marcos. He devoted much attention to the social history of the colonial period in Perú, with particular emphasis on demography, and shifts in populations during this period. This work will to a considerable extent close the gap between the data of archeological studies in the Virú Valley in north Perú, made by Smithsonian and other scientists, and the contemporary studies made by Dr. Holmberg and teachers and students of the Instituto de Estudios Etnológicos, thus completing one of the longest sequences of culture history known from any part of the world. Dr. Kubler made a brief trip in March 1949 to Bogotá and Popayán, to investigate

documents in the Colombian capital dealing with demographic movements on the west coast of South America in colonial times, and to consult with Dr. Crist on Institute of Social Anthropology matters. In June 1949 he served as Adviser to the American Delegation at the Third Annual Interamerican Indian Congress, held in Cuzco.

Publications.—Institute of Social Anthropology Publications Nos. 8 and 9 appeared during the year and Nos. 10, 11, and 12 were in press. These are listed with the publications of the Bureau of American Ethnology.

RIVER BASIN SURVEYS

The River Basin Surveys, organized in 1946 as a unit of the Bureau of American Ethnology to carry into effect a memorandum of understanding between the Smithsonian Institution and the National Park Service providing for the salvage of archeological and paleontological materials that will be lost as a result of the nation-wide program for flood control, irrigation, hydroelectric, and navigation projects sponsored by the Federal Government, continued its operations during the year. As in the past, the investigations were conducted in cooperation with the National Park Service and the Bureau of Reclamation of the Department of the Interior, the Corps of Engineers, Department of the Army, and a number of nongovernmental local institutions. The work was financed by the transfer of \$145,400 (\$20,000 of which was appropriated in the 2d Deficiency Act and did not become available for actual use until the beginning of fiscal 1950) to the Smithsonian Institution by the National Park Service. The money comprising these funds was derived in part from the Bureau of Reclamation and in part from the National Park Service.

Activities in the field consisted mainly of reconnaissance or surveys for the purpose of locating sites that will be involved in construction work or are so situated that eventually they will be inundated. There was a limited testing of sites to determine their nature and extent, where such was deemed essential, and at seven locations extended excavation or intensive testing was carried on. The surveys covered 67 reservoir areas scattered throughout 8 river basins and 14 States. At the end of the year the total of the reservoir areas surveyed or where some digging has been done since the start of the program in July 1946 had reached 154 located in 21 States. During the course of the work 2,107 archeological sites have been recorded, and of that number 456 have been recommended for excavation or further testing. Thus far preliminary appraisal reports have been finished for all the reservoirs, and 97 have been mimeographed for distribution to the cooperating agencies. Where several reservoirs form a unit in a single

drainage subbasin the information on all is included in a single report, so that the 97 mimeographed pamphlets contain information on some 130 of the reservoir projects. In addition to the archeological papers, one comprehensive report on the paleontological problems in the Missouri Basin was also issued. More detailed technical reports completed for a number of projects have appeared in scientific journals or are awaiting publication.

The distribution by States of all the reservoirs investigated, as of the close of the fiscal year, is as follows: California, 16; Colorado, 23; Georgia, 2; Idaho, 9; Illinois, 2; Iowa, 3; Kansas, 6; Minnesota, 1; Montana, 5; Nebraska, 16; New Mexico, 1; North Dakota, 13; Oklahoma, 5; Oregon, 12; South Dakota, 9; Tennessee, 1; Texas, 10; Virginia, 1; Washington, 9; West Virginia, 2; Wyoming, 8. Excavations completed during the year were: Colorado, 1; Nebraska, 1; North Dakota, 1; Oklahoma, 1; Oregon, 1; Washington, 1. In a number of cases the digging was started in the previous fiscal year and continued over into fiscal 1949. Other States where excavations were made in prior years are: Kansas, 1; New Mexico, 1; Texas, 1; and Wyoming, 1.

As has been the case since the start of the River Basin Surveys program, staff men in the field received full cooperation from representatives of the National Park Service, the Bureau of Reclamation, the Corps of Engineers, and various State agencies. Temporary office and laboratory space was provided at some of the projects, transportation and guides were furnished at others, and in several instances labor and mechanical equipment made available by the construction agency materially increased excavation operations. Had it not been for this assistance it would not have been possible to accomplish all that was done during the year. The National Park Service was primarily responsible for obtaining the funds which supported the program and continued to serve as the liaison between the Smithsonian Institution and the other governmental agencies, both in Washington and through its several regional offices. The untiring efforts of Park Service personnel played a large part in furthering the progress of the program as a whole.

The main office in Washington had general direction and supervision over the work in Oklahoma, Texas, Minnesota, North Dakota (in the drainage of the Red River of the North), Iowa, Illinois, Colorado (outside of the Missouri Basin), and California. In the Missouri Basin, direction of the program was from a field headquarters at Lincoln, Nebr., where all the materials collected by the survey and excavation parties were also processed. Activities in the Columbia Basin were supervised from a field office located at Eugene, Oreg.

Washington office.—Throughout the fiscal year the main head-

quarters of the River Basin Surveys continued under the direction of Dr. Frank H. H. Roberts, Jr. Carl F. Miller, Joseph R. Caldwell, and Ralph S. Solecki, archeologists, were based on that office, although Caldwell and Solecki did not work full time for the Surveys.

Richard P. Wheeler was appointed archeologist on the staff on August 27, and from that date until May 16 functioned under the direction of the Washington office, although all his work was done in the field. On May 16 he was transferred to the Missouri Basin and from then until the close of the year was based on the Lincoln headquarters.

Mr. Miller spent most of the year in the office preparing reports based upon material gathered in the field during the previous year, and assisting the Director in reviewing the literature pertaining to archeological manifestations occurring in areas where additional reservoir projects are proposed. His "Appraisal of the Archeological Resources of the Clark Hill Reservoir Area, South Carolina and Georgia" was completed and mimeographed for distribution in December. Another article, "Early Cultural Manifestations Exposed by the Archeological Survey of the Buggs Island Reservoir in Southern Virginia and Northern North Carolina," was published in the *Journal of the Washington Academy of Sciences*, vol. 38, No. 2, December 1948. A paper based on information obtained during the survey of the Clark Hill Reservoir, "The Lake Spring Site, Columbia County, Georgia," was to appear in *American Antiquity*, vol. 15, No. 1, July 1949. Several others have been accepted for publication elsewhere. Mr. Miller made two trips to Clarksville, Va., in the late winter and early spring, the first for the purpose of investigating unauthorized pot-hunting activities in the Buggs Island Reservoir area, and the second to speak before the Archeological Society of Virginia on the problems of the Buggs Island archeological program. He also went to Richmond, Va., where he spent 2 days at the Valentine Museum examining manuscripts and other documentary materials pertaining to early explorations and surveys in Virginia, northern North Carolina, and eastern West Virginia in an effort to obtain further data bearing on the aboriginal history of the Buggs Island area.

In July and early August Mr. Caldwell collaborated with Mr. Miller in working over the materials collected during the Clark Hill Reservoir survey. During that period he prepared a paper, "The Rembert Mounds, Elbert County, Georgia," based on new information obtained at Clark Hill. Another article, "Palachacolas Town, Hampton County, South Carolina," was printed in the *Journal of the Washington Academy of Sciences*, vol. 38, No. 10, October 15, 1948. On August 19 Mr. Caldwell joined Dr. Robert E. Bell, of the University of Oklahoma, at Wagoner, Okla., and began the excavation of a large mound

at the Norman Site in the Fort Gibson Reservoir basin. That work continued until September 22. Mr. Caldwell returned to Washington on September 25 and on October 3 was granted leave of absence to join an expedition of the Universities of Chicago and Pennsylvania in Iraq and Iran. He returned to duty on the staff of the River Basin Surveys June 26, 1949, and began work on materials from the Allatoona Reservoir basin in Georgia.

Ralph S. Solecki devoted the summer and fall months to the preparation of reports on his work at the Bluestone and West Fork projects in West Virginia. The Bluestone paper was mimeographed and distributed in December and that for the West Fork in March. Mr. Solecki also prepared a detailed article, "An Archeological Survey of Two River Basins in West Virginia," which was published in *West Virginia History*, vol. 10, Nos. 3 and 4. In December he was temporarily transferred to the regular staff of the Bureau of American Ethnology and was sent to Natrium, W. Va., to excavate a mound on the property of the Pittsburgh Plate Glass Co. The latter organization planned to level the mound to make room for new buildings and in order that nothing of value might be destroyed made arrangements with the Bureau to have it done properly, providing the necessary labor for the project. Mr. Solecki returned to the River Basin Surveys on January 12. In following months he continued to work on the material from West Virginia and on May 8 was transferred to the Smithsonian Institution staff so that he could accompany a party of the United States Geological Survey to Alaska for an archeological reconnaissance along the upper Kukpowruk and Kokolik Rivers in northern Alaska. At the close of the fiscal year he reported having located some 50 late Eskimo sites.

California.—Investigations in California were not as extensive as in previous years and were limited to three reservoir projects. In October David A. Frederickson and Albert Mohr, field assistants of the River Basin Surveys, working under the general supervision of Francis A. Riddell, assistant archeologist of the California Archeological Survey, University of California, and in cooperation with the latter organization, examined the areas to be flooded by the Black Butte, Farmington, and New Melones Reservoirs, all Corps of Engineers projects.

The Black Butte Dam is to be built in Stony Creek, and the basin it will flood lies in Glenn and Tehama Counties, a region formerly occupied by the Wintun. The survey located 26 sites in the area and it is believed that excavations in a number of them would provide a reasonably accurate and balanced picture of the material culture of the Indians who lived there.

The Farmington Dam is planned for Littlejohn Creek, and the

reservoir formed by it will inundate areas in both San Joaquin and Stanislaus Counties. It would seem that in aboriginal times that section was more suitable for occupation than it has been in recent years because 24 sites were found there. Most of them are of the surface variety, indicating seasonal occupation, but some have cultural deposits with artifacts, bone, and shell occurring in some abundance. All the artifacts are alike, both in types and material, and are of particular interest because they consist in the main of crude core tools, cores, and flake tools, with only a few blade fragments and no arrow-heads. The material from which they were made occurs in the local stream beds in the form of cobbles. Excavations in a number of the sites are recommended for the purpose of obtaining information both as to their probable position in the chronological sequence of the area and as to their relationships.

The New Melones Reservoir will fill a deep and narrow valley formed by the Stanislaus River in Calaveras and Tuolumne Counties. The area is one in which there was considerable mining activity at one time, and there is an existing reservoir which has modified the surface of the ground to some degree. Consequently only four sites were noted, despite the fact that the Northern Miwok once inhabited the region, and no further archeological activities were recommended.

Colorado.—Because of the physiographic character of the area included within the political boundaries of Colorado the numerous projects there occur within the limits of several drainage systems. Consequently some of the archeological investigations have been conducted as a part of the Missouri Basin program, while others have been carried on as separate units of the Surveys as a whole. Only the latter are discussed in this section of the report.

At the start of the fiscal year Donald Eastman and Gary L. Yundt, field assistants, were continuing reconnaissance of the area involved in the Taylor Lake Enlargement of the Gunnison-Arkansas project. They completed this work on July 7, after having located only two sites that will be covered by the waters of the larger lake resulting from the construction of a new dam. The sites apparently were former camps and only surface material was present. The latter, however, is crude in character and suggests a much earlier cultural horizon than that of the late nomads. Neither of the sites showed sufficient depth to warrant excavation, and no further work is recommended for that project. From Taylor Lake, Eastman and Yundt proceeded to the Cimarron Damsite located on the Gunnison River just below the confluence of the latter and the Cimarron. The area to be flooded by this project had previously been surveyed in part by the Chipeta Chapter of the Colorado Archeological Society, Montrose, which made it possible for the Survey men to complete

their work by July 17. All the sites located, eight in number, indicate that they were camping places, and the surface materials collected from them are typical of the late nomadic Indians of the region. Similar sites are abundant outside of the basin of the proposed reservoir, hence no further investigations are needed there. Eastman and Yundt returned to Gunnison, Colo., from the Cimarron project and, having completed their reports, resigned from the River Basin Surveys on July 23. During the course of their investigations they worked under the general direction and supervision of Dr. C. T. Hurst of Western State College, Gunnison, who had cooperated with the River Basin Surveys on a number of previous surveys.

Arnold M. Withers, archaeologist, completed reconnaissance of nine proposed reservoir areas in the Blue-South Platte project, which he had started toward the end of the previous year, and examined six of those in the Gunnison-Arkansas project east of the Rocky Mountains. All the proposed reservoirs of the Blue-South Platte project, Two Forks, Shawnee, Blue, Snake, Tenmile, Ruedi, Pando, Piney, and Empire, are located in the high mountain valleys of the Colorado Rockies at altitudes ranging from 8,000 to 10,000 feet above sea level. They will be situated in Douglas, Park, Summit, Eagle, Pitkin, and Clear Creek Counties. Only six definite archaeological sites were found in the nine reservoir areas, although further surveys are recommended for the Snake and the upper part of the Two Forks, and they appear to have been temporary camps occupied by a people engaged in hunting and gathering wild food products. At none of them are the deposits of sufficient depth to warrant excavation. The materials collected from the surface suggest that the sites are prehistoric, although they have no great age, and that they probably are attributable to Ute Indians.

The six proposed reservoirs of the Gunnison-Arkansas project, the Graneros, Cedarwood, Ben Butler, Pueblo, Higbee or Purgatoire, and Horse Creek, are in the broken country of the High Plains along the Arkansas or its tributaries in Pueblo, Huerfano, Otero, and Bent Counties, Colo. The rapid survey of the area by Withers produced a total of only 13 sites for the project. They consist of rock shelters and open camps. At a number of the latter, tipi rings were noted. Although the small number of sites indicates that the area was sparsely populated, the character of the materials collected from them suggests that a long period of time is represented. Testing is recommended for some of the rock shelters and two of the stone-circle sites, but none appears to be worthy of complete excavation. A more intensive investigation of the Pueblo and Purgatoire reservoir basins is indicated if the projects are authorized and construction work is started. Withers completed his work and left the Surveys on August 14.

During the investigations he was provided with a base of operations by the University of Denver.

Preliminary reconnaissance of the eight reservoirs included in the Colorado-Big Thompson project by the University of Colorado was completed in the autumn of 1947. In accordance with recommendations made at that time, the River Basin Surveys arranged for a more intensive survey and the testing of some sites in the Granby Reservoir on the Colorado River in Grand County. That work was carried out during August and September by Robert F. Burgh, field assistant, who was on leave of absence from the University of Colorado Museum, aided by William Woodard and Byron W. Houseknecht, student assistants. Only four sites were located in the area to be flooded, and two of those showed only surface traces of stone chips and a few implements. Another consisted of stone circles, presumably tipi rings, but yielded no artifacts. The fourth was a camp site located on the west side of the basin on a terrace adjacent to Stillwater Creek. Trenching of the site produced a variety of cultural remains consisting of hearths, potsherds, stone projectile points, stone scrapers, manos, metate fragments, and animal bones. No traces of house remains were found, and the occurrence of fireplaces at varying depths below the surface suggests that there were repeated but casual occupations of the terrace during successive seasons without any permanent habitation. Potsherds from the site were of two kinds, cord-marked and corrugated. The cord-marked is from a cooking ware of Woodland type, while the corrugated undoubtedly came from the Northern Periphery of the Southwest. The pottery indicates that the site probably dates between A. D. 900 and 1300. The bulk of the material obtained there shows that the affiliations were clearly with the prehistoric Plains cultures, particularly those responsible for the camp sites along the foothills in northeastern Colorado.

Conclusions, based on the results of the work in that area, are that no further investigations are warranted in the Colorado-Big Thompson project unless construction operations accidentally uncover unsuspected remains. West of the Continental Divide there are no sites as good as the one examined in the Granby Reservoir, while east of it there are numerous examples outside the reservoir basins which not only appear to have the same cultural identity as those within them but to offer greater promise.

Columbia Basin.—Work in the Columbia Basin was based on the field headquarters at Eugene, Oreg., where office and laboratory space was provided by the University of Oregon. Dr. Philip Drucker, on detail from the Bureau of American Ethnology, continued to direct the program until October 1 when he returned to Washington and his regular duties prior to being granted military leave beginning October

22. After Dr. Drucker's departure from Eugene, Homer Douglas Osborne, archeologist, was appointed acting field director and placed in charge of the office there. He continued in that capacity throughout the remainder of the year.

From July to early September, two parties consisting of two men each, were engaged in the investigation of reservoir areas in the Columbia Basin. During that time they explored 15 reservoir basins, 6 of which are Corps of Engineers projects, and 9 of which are projects of the Bureau of Reclamation. The Corps of Engineers projects include the 4 navigational reservoirs on the lower Snake River in Washington, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite. In addition Lucky Peak Reservoir basin in Idaho was examined, and the results of the survey of Chief Joseph (Foster Creek) Reservoir in east-central Washington initiated some years ago by the University of Washington were checked and the survey was completed. The work done in Bureau of Reclamation reservoirs involved the examination of sites in the Deschutes project, Benham Falls and Prineville Reservoirs, and checks of the proposed enlargement of Wickiup and Crane Prairie Reservoirs. In addition a series of small reservoirs in eastern Oregon and central Idaho were surveyed. They were: Mason, Ryan Creek, and Bully Creek in northeastern Oregon; and Lost Valley Enlargement and Horse Flat Reservoirs in Idaho. Within the boundaries of those 15 reservoir basins a total of 128 archeological sites were found and recorded.

Excavation projects were carried out in the McNary Reservoir area, Oregon-Washington, and in the O'Sullivan (Potholes) Reservoir, Washington. The work at McNary was a cooperative undertaking between the River Basin Surveys and the University of Oregon, while that at O'Sullivan was a joint venture between the Surveys and the University of Washington.

Investigations at McNary were carried on from August 5 to September 11 under the direction of Homer Douglas Osborne. The digging was done by students from various west coast universities. Extensive tests were made in two sites on Berrian Island, Wash., which had been designated as a source of aggregate for dam construction, and at an important one on the Oregon side of the river. In addition to previously unknown information about local Indian village and house patterns, the excavations produced 48 burials and 1,870 artifacts. The skeletal material provides one of the largest series thus far available for study and should throw considerable light on the physical characteristics and relationships of the people. The artifacts will give a good cross section of the material culture prevailing at the time of first contact with European influence.

The O'Sullivan project was well under way at the start of the fiscal

year and continued until August 19. Richard D. Daugherty, archeologist, was in charge of the party, which consisted of students from the University of Washington. The scene of operations was a village site located on the shores of Moses Lake, an area which will be inundated when the dam is completed. Three house-pit depressions and the terrain immediately surrounding them were carefully examined. Good data were obtained on the form and construction of the houses, and the series of artifacts recovered during the digging will aid in determining the cultural status of the people. The absence of all European objects indicates that the site antedates the period of exploration and early trading posts. The results at O'Sullivan, in general, indicate that more intensive work should be done there.

Special mention should be made of the excellent cooperation on the part of other governmental agencies. The National Park Service, through the Region Four office at San Francisco and the Columbia Basin Recreational Survey office at Portland furnished the Eugene office with current information on reservoir priorities, construction schedules, and field maps. The Bureau of Reclamation, through the Region One office in Boise, Idaho, not only supplied maps of reservoir areas and information on their projects, but greatly facilitated the archeological investigations by placing vehicles at the disposal of the survey parties. The Corps of Engineers, through the office of the Division Engineer, and also the Portland and Seattle District offices, provided maps and other essential information. In addition the Portland District office made a vehicle available for use at the McNary project, furnished a temporary headquarters, and provided assistance in the mapping of sites.

Throughout the period of active work Dr. Drucker made numerous trips from the Eugene office to the various parties and the excavation projects. He also met with Dr. Robert F. Heizer, Director, California Archeological Surveys, and assisted in perfecting plans for the cooperative work to be carried on by that organization. After completing arrangements for maintaining the Eugene office during the winter months, he returned to Washington on October 1.

At the start of the year George L. Coale, archeologist, and Francis A. Riddell, Harry S. Riddell, Jr., and Homer Douglas Osborne, field assistants, were engaged in the survey of the Benham Falls, Prineville, Wickiup, and Crane Prairie Reservoirs. That work was completed on July 11, and Coale and Osborne returned to Eugene to assist Dr. Drucker in making preparations for the excavations at the McNary Reservoir. The two Riddells proceeded to northeastern Oregon where they made a reconnaissance of the Mason Creek and Ryan Creek Reservoirs. The surveys there being finished on July 16, they moved to Chief Joseph (Foster Creek) where on July 26 they completed

the investigations previously started by the University of Washington. Francis A. Riddell resigned from the Surveys on July 30. George L. Coale met Harry S. Riddell, Jr., at Pasco, Wash., on the 27th, and the two proceeded from there to Ice Harbor and Lower Monumental Reservoirs. After their reconnaissance of those two projects they went on to the Lucky Peak, Lost Valley, and Horse Creek Reservoirs in Idaho, and the Bully Creek Reservoir in Oregon. William W. Burd, who was appointed a field assistant on August 16, and Joel L. Shiner, who was promoted from the crew at McNary to field assistant, spent the period from August 18 to 30 examining the Little Goose and Lower Monumental Reservoirs for archeological remains. Burd returned to Eugene and resigned on August 31, while Shiner rejoined the party at the McNary excavations and continued with it until September 9 when he resigned. After completing the field work at Moses Lake, Richard D. Daugherty proceeded to Seattle, Wash., where he processed and studied the materials obtained from the excavations and prepared a report on the results of the investigations. His appointment as archaeologist terminated on September 16.

As previously mentioned, Osborne spent the first few weeks of the year on survey duties and was then recalled to Eugene to aid in preparations for the McNary project. He went with the party to that reservoir on August 5 and on August 16 was promoted to archaeologist and placed in charge of the excavations. Upon his return to Eugene in September he was made Acting Field Director, and continued to function in that capacity throughout the remainder of the year. During the fall and winter months he wrote the preliminary appraisal reports for the 15 reservoirs surveyed during the summer, prepared a summary report and a longer, more detailed manuscript on the McNary excavations, and made compilations of data on historical references, ethnological descriptions, and trade goods to be used as ready sources for information on the Columbia Basin. During February he made a survey of the Big Cliff Reservoir and checked the various bank-control projects of the Corps of Engineers along the Willamette River and its tributaries. On May 26 and 27 he participated in a conference at Pendleton, Oreg., where representatives of the Corps of Engineers, the National Park Service, and the Bureau of Indian Affairs discussed the problem of the removal of Indian burials from areas that are to be flooded. Throughout the winter months Osborne was assisted in the laboratory by Lloyd Collins and Hiroto Zakoji, students of the University of Oregon.

Illinois.—Archeological studies in Illinois consisted of the examination of the records of previous surveys in the Illinois River Basin and the investigation of two reservoir areas where dams were under construction.

During February Richard P. Wheeler conferred with the District Engineer at Chicago about the flood-control program for the Illinois River Basin, discussed archeological problems involved with Dr. John C. McGregor, associate professor of anthropology at the University of Illinois, and with Dr. Kenneth G. Orr, assistant professor of anthropology at the University of Chicago. March 10 to 18, Wheeler checked the survey files of the Department of Anthropology and worked in the Harper Library, at the University of Chicago. Leaving Chicago he proceeded to Springfield, Ill., where he conferred with Dr. Thorne Deuel, Director of the Illinois State Museum. From March 21 to 25 he made a reconnaissance of the Fondulac and Farmdale Reservoir basins, the dams then being built, on Farm Creek, in Tazewell County, Ill. No archeological sites were found in those areas, and no further work was recommended.

In April Wheeler prepared a preliminary report, "Archeological Resources of the Proposed or Considered Reservoirs in the Illinois River Basin, Central and Northern Illinois," which embodied a synopsis of present knowledge of the archeology of this region and provided a list of known sites (based on the site list prepared for the River Basin Surveys in September 1947 by Dr. J. C. McGregor) in 10 of the 15 proposed reservoirs in the Illinois River Basin for which maps are available.

On May 16 Wheeler was transferred to the Missouri Basin, and his activities from then until the end of the year are included in that portion of the report.

Iowa.—Work in Iowa was confined for the most part to surveys of two reservoir basins and the area immediately adjacent to the dam site of a third where preliminary construction activities were already under way.

Richard P. Wheeler spent the period December 6 to 10 at the Red Rock Reservoir project, on the Des Moines River, and December 13 to 15 at the Rathbun Reservoir on the Chariton River. During the progress of the work he consulted with Dr. Charles R. Keyes, Director of the Archeological Survey of Iowa, about the character and extent of the archeological remains in the two areas. In his reports prepared at the conclusion of his field investigations, Wheeler records 15 mound and occupation sites in the Red Rock basin, 4 of which will be involved in the dam construction, and 6 in the Rathbun area. More intensive studies under more favorable field conditions were recommended for both reservoirs.

Between January 24 and February 3, Wheeler made a preliminary reconnaissance of the Coralville Reservoir, on the Iowa River, in Johnson and Iowa Counties, Iowa. Eight mound sites and one occupation site were located. Ten other sites, recorded prior to the

survey, could not be found because of the deep snow cover. Further work will be necessary before recommendations can be made for the salvage of archeological remains in that reservoir area.

Missouri Basin.—The Missouri Basin project, as in previous years, continued under the general direction of Dr. Waldo R. Wedel and was based on the field headquarters at Lincoln, Nebr. During the fiscal year 12 new reservoir basins were surveyed for archeological remains; two areas only briefly examined in former seasons were revisited and subjected to intensive reconnaissance; while comprehensive excavations were carried on at one location. In addition to those activities and certain paleontological investigations, laboratory and office work were carried on throughout the year.

As the fiscal year opened, three archeological units and one paleontological unit were engaged in field work. The largest project was the excavation program at Medicine Creek, Nebr., under the field direction of M. F. Kivett, archeologist, with George Metcalf as assistant. The work was made possible through an agreement with the Bureau of Reclamation under which the Bureau provided labor and power equipment while the River Basin Surveys provided the technical supervision and maintained the scientific records. This project terminated on August 20, having produced a large body of data and artifacts for several inadequately known prehistoric culture horizons. Aside from the scientific returns of the operation, it is important to note that the applicability of power machinery to the excavation of aboriginal village sites under careful technical supervision was amply demonstrated. The findings add much new information to that previously obtained elsewhere in the Central Plains through the small-scale sampling of many sites.

A second unit under J. T. Hughes, archeologist, with J. M. Shippee as assistant, was at work in Angostura Reservoir, South Dakota. Intensive survey there added numerous sites to those recorded during preliminary reconnaissance in 1946; and also disclosed the presence of at least one site that may have an antiquity of several thousand years. Because of the extreme scarcity of data from this early period, and the usual difficulty of working such sites, it is imperative that further excavation be carried on there. From September 15 to 30 Hughes and Shippee carried on preliminary reconnaissance at the Edgemont and Keyhole Projects in Wyoming, and at the Pactola and Johnson Siding Reservoir basins in South Dakota. At Edgemont 28 sites were recorded, while 29 were noted at Keyhole. Only one was noted at Pactola and none at Johnson Siding.

A third unit under Paul L. Cooper carried on excavations at the Heart Butte Reservoir basin, North Dakota, through the month of July, and then transferred its activities to the proposed lower Oahe

Reservoir project on the Missouri River a few miles above Pierre, S. Dak. On the basis of findings by that unit, it appears unlikely that remains of any great importance to archeology will be lost at Heart Butte. At Oahe, 61 sites were recorded between Pierre and the Cheyenne River, a distance of about 40 miles. They include some of the largest, best preserved, and most impressive Indian village remains in the Missouri Basin. Most of them are virtually untouched by trained archeologists and, with one or two possible exceptions, none has been adequately tested by excavation. Five of the sites will be affected almost as soon as construction work begins on the dam site, the access roads, and the railroad classification yards. Hence, salvage operations will be necessary at an early date. Because of the abundance and variety of remains, comprehensive excavation has been recommended to begin soon and to be carried forward vigorously so that a representative sample of the materials to be affected by Oahe Reservoir may be saved.

From November 9 to 24 Cooper and Shippee excavated a burial mound in the spillway area of Fort Randall Dam, South Dakota. The Corps of Engineers provided a bulldozer and operator as needed, and assisted in numerous other ways. Without that cooperation, the work there would not have been possible. The findings, although not spectacular, are important because burial mounds are extremely rare on that portion of the Missouri, and their temporal and cultural relationships to other archeological complexes of the region can be determined, if at all, only through controlled excavations by trained investigators.

A paleontological unit under Dr. T. E. White was in the field from July 1 to October 1. It worked at the Boysen Reservoir, Wyoming; in the Canyon Ferry Reservoir area on the Missouri River north of Townsend, Mont.; at the Angostura Reservoir, South Dakota; and at the Cedar Bluff Reservoir on the Smoky Hill River in Kansas.

Limited field work was resumed in the spring. Richard P. Wheeler, archeologist, left Lincoln on May 27 for preliminary reconnaissance at several hitherto unvisited reservoir projects and for further survey of others previously examined in preliminary fashion. Projects visited by Wheeler prior to June 30 include Rocky Ford, Philip, Bixby, and Shadehill, in South Dakota; Cannonball and Dickinson, in North Dakota; Moorhead, in Wyoming-Montana, and Onion Flat in Wyoming.

Among the particularly gratifying features of the year's field work were the results achieved through use of power machinery and the direct cooperation extended by the Bureau of Reclamation at Medicine Creek and by the Corps of Engineers at Fort Randall Reservoir. Such cooperative work, in terms of research accomplished, is the most

economical way of salvaging archeological remains on the scale needed. Application of the same procedures, including mechanized earth-moving operations, to other projects seems to be the only way of obtaining irreplaceable scientific data in the little time left for its recovery.

In the laboratory 39 maps were drawn. Many of them were field maps, others were site and reservoir maps for use with published reports. Throughout the winter specimens were selected and photographed as analysis for technical reports proceeded. Including field photographs, a total of 918 negatives and 374 color transparencies were processed; 61 lantern slides were added to the slide series; 918 prints were made, cataloged, and filed; 1,008 prints were made for report illustrations and reference purposes; and 350 enlargements were made for publicity and reference use.

All specimens collected during the field season, a total of 45,233, were cleaned, numbered, cataloged, and stored. The majority of them came from Medicine Creek, Angostura, and Oahe Reservoirs. Samples of bone, shell, and vegetal specimens from various sites were packed and sent to specialists elsewhere for identification. In addition, soil samples from some of the sites were sent out for analysis, and wood and charcoal specimens were sent away for tree-ring studies.

The skeleton of an adolescent covered with thousands of shell beads, sent to Lincoln in a plaster case from the Harlan County Reservoir, Nebraska, in 1946, was mounted permanently for exhibit purposes. Pottery restoration, principally of Medicine Creek material, continued throughout the spring months, 17 earthenware vessels having been restored by June 30.

Information concerning over 129 sites was added to the site file, and 45 maps were indexed and added to the map reference file.

On July 1, J. Joseph Bauxar, archeologist, was stationed at the Lincoln, Nebr., headquarters, continuing the ethnohistorical research project he had started the preceeding year. The material collected consisted of such information as is pertinent to the archeologists' problem of determining the ethnic affiliations of the archeological complexes in the Missouri River Basin. Some 30 tribes and subtribes are represented in the Tribal Culture File. On January 9, 1949, Mr. Bauxar was transferred to the Oklahoma project of the River Basin Surveys and proceeded to Norman for the purpose of analyzing materials from the Norman site in the Fort Gibson Reservoir.

Wesley L. Bliss, archeologist, devoted the time from July 1 until January 8 in the preparation of a general article "Birdshead Cave, a Stratified Site in the Wind River Basin, Wyoming," and a technical report on the same project. In late August he visited the sites in the Medicine Creek area being excavated by the State Museum of the

University of Nebraska and in October accompanied a group from that institution on a trip to Signal Butte in western Nebraska for the purpose of reexamining the early sites at that location. On the basis of information obtained during the course of his work, he prepared a paper "Early and Late Lithic Horizons in the Plains" which was presented before the Sixth Conference for Plains Archeology at Lincoln in November. Mr. Bliss left the River Basin Surveys staff on January 8.

In addition to the field work previously mentioned, Paul L. Cooper in September accompanied Dr. Waldo R. Wedel, Dr. Gordon Baldwin of the National Park Service, and Dr. J. O. Brew and Frederick Johnson of the Committee for the Recovery of Archeological Remains, on an inspection trip to Missouri Basin archeological sites in Wyoming, Montana, North Dakota, South Dakota, and Nebraska. Throughout the remainder of the year his activities were centered in the laboratory at Lincoln. Until March 24 he was in charge of the Lincoln headquarters during such times as Dr. Wedel was in Washington, but from that date until June 30 devoted most of his attention to analyzing the data and specimens obtained during the field season and in the preparation of reports. He wrote a summary of the work done at two reservoirs in South Dakota, "Recent Investigations in Fort Randall and Oahe Reservoirs, South Dakota," which was published in *American Antiquity*, vol. 14, No. 4, April 1949.

Robert B. Cumming, Jr., archeologist, continued to plan and supervise the laboratory procedures, as mentioned in an earlier paragraph, and from March 24 until June 30 was in charge of the Lincoln office when Dr. Wedel was not present at the laboratory.

Following the summer field work Jack T. Hughes, archeologist, spent the remainder of the year in the laboratory studying the data and materials collected from the various reservoirs he had examined and writing reports on the results of his work. He prepared a memorandum on Cheyenne Basin archeology for the National Park Service and completed an article, "Investigations in Western South Dakota and Northeastern Wyoming," which was published in *American Antiquity*, vol. 14, No. 4, April 1949. He collaborated with Dr. Theodore E. White in writing a manuscript "The Long Site, an Ancient Camp in Southwestern South Dakota." The latter is a preliminary account of the archeology and physiography of one of the most significant sites yet found in the Angostura Reservoir basin. Hughes also prepared a paper, "Archeology and Environment in the Western Great Plains," which he presented at the Sixth Conference for Plains Archeology held in Lincoln in November. In addition he wrote a paper, "An Experiment in Relative Dating of Archeological Remains by Stream Terraces," which he read before the Anthropology

Section of the Nebraska Academy of Sciences in May. He wrote a memorandum on geological deposits and archeological remains in the Tiber Reservoir basin, on the Marias River in northern Montana, for the United States Geological Survey, and "A Note on Fireplaces" for the Plains Archeological Conference Newsletter. Earlier in the year he had prepared an article, "Naming Projectile Point Types," for the same journal. At the close of the year he was occupied with a report on the Nebraska State Historical Society's investigations at the Barn Butte site in western Nebraska and was continuing his work on the development of a correlation table dealing with early remains in the western United States.

Upon the completion of the excavation project at the Medicine Creek Reservoir, Marvin F. Kivett, archeologist, returned to Lincoln on September 1 and began the preparation of a brief preliminary report for the use of H. E. Robinson, District Manager of the Bureau of Reclamation. Included in it was a tabulation of work completed at various sites in the Medicine Creek Reservoir basin. After that manuscript was finished Kivett wrote a summary account, "Archeological Investigations in Medicine Creek Reservoir, Nebraska," which was printed in *American Antiquity*, vol. 14, No. 4, April 1949. He then turned his attention to completing a laboratory analysis of the more than 30,000 specimens collected at Medicine Creek and to a study of comparable materials gathered in the same area by parties from the Nebraska State Historical Society and placed at his disposal, with the accompanying data, for inclusion in the final technical report. In addition, Mr. Kivett wrote a technical paper on the prehistoric ossuary which he excavated at the Harlan County Reservoir in the fall of 1946, and another "Archeology and Climatic Implications in the Central Plains," which was presented before the Sixth Conference for Plains Archeology. Two brief articles, one concerning the use of power equipment in archeological work and the other dealing with pottery nomenclature, were printed in the Plains Archeological Conference Newsletter.

One trip of 4 days was made by Kivett to the Medicine Creek project during October for the purpose of marking trees from which sections for dendrochronological studies were to be cut under the supervision of the Bureau of Reclamation. In May he made a 1-day trip to the Harlan County and Medicine Creek Reservoirs to point out to members of the Missouri Basin Inter-Agency Committee archeological work completed and that contemplated for those reservoirs. Mr. Kivett resigned from the River Basin Surveys on May 31 to accept an appointment as Assistant Director of the Museum of the Nebraska State Historical Society.

George Metcalf, field and laboratory assistant, participated in the

excavations at Medicine Creek and, after his return to the Lincoln headquarters on August 24, assisted in the cleaning and cataloging of the last consignment of specimens from the project. From September 12 until October 20 he supervised and aided in the processing of some 7,000 specimens recovered from Medicine Creek sites by the Nebraska State Historical Society. As a part of that task all suitable shell, bone, and vegetal material was listed and prepared for submission to specialists for identification. Throughout the winter and spring months he worked with Mr. Kivett in the analysis of the Medicine Creek materials and wrote sections on worked bone, shell, and pottery for inclusion in the final technical report. He also assisted in the selection of specimens and the arrangement of photographic plates for the final report. At the end of the fiscal year he was engaged in making an analysis of the house remains in the Medicine Creek area.

J. M. Shippee, field and laboratory assistant, returned to Lincoln with the Hughes party on October 1 and from then until November 8 supervised the dismantling of the laboratory and its reinstallation in new quarters. Mr. Shippee then accompanied Mr. Cooper to the Fort Randall Reservoir, where he assisted in the excavation of a burial mound located on the site of the dam spillway. He returned to Lincoln in late November and spent the remainder of the year in the restoration of pottery and other specimens and in the cleaning and mounting, for exhibition purposes, of a juvenile skeleton which had been removed intact from an ossuary at the Harlan County Reservoir. He prepared a paper, "Some Problems of the Nebo Hill Complex," which was read before the Anthropological Section of the Nebraska Academy of Sciences on May 7. At the close of the year he was preparing and assembling equipment for the various parties starting for the field.

Richard P. Wheeler, archeologist, was transferred to the Missouri Basin in May and on May 27 left Lincoln to make a series of preliminary surveys at reservoir projects in South Dakota, North Dakota, Montana, and Wyoming. By the end of the year he had visited eight reservoir areas. On June 30 he was at Fort Washakie, Wyo., where he obtained permission from the Business Council of the Shoshones and Arapahos to make preliminary surveys of the proposed Soral Creek and Raft Lake reservoir basins, which are located in the Wind River Indian Reservation, immediately after the start of the new year.

Dr. Theodore E. White, paleontologist, confined his activities, with one minor exception, to work on the Missouri Basin problems throughout the fiscal year.

From July 1 to 12 the lower Eocene deposits in the Boysen Reservoir area on the Big Horn River north of Shoshoni, Fremont County, Wyo., were prospected for fossils. Five fossiliferous "pockets," which

will be inundated when the reservoir is flooded, were found. The results of the work there confirmed the conclusions of the members of the United States Geological Survey who had mapped the structure and stratigraphy of that area.

From July 14 to August 19 the Oligocene and Miocene deposits in the Canyon Ferry Reservoir area on the Missouri River north of Townsend, Broadwater County, Mont., were prospected for fossils. Material was obtained from three localities in the Oligocene and two in the Miocene. All those localities will be inundated.

After the close of the work at Canyon Ferry, White's party proceeded to the Angostura Reservoir on the Cheyenne River in Fall River County, S. Dak., to make a physiographic study of the area in connection with an early-man site. The period from August 21 to September 3 was spent in collecting data for that study. The party returned to Lincoln, Nebr., on September 4 in order to prepare a preliminary report on the results of the physiographic study.

From September 23 to October 1 the Upper Cretaceous Carlile Shale in Cedar Bluff Reservoir on the Smoky Hill River south of Wakeeney, Trego County, Kans., was prospected for vertebrate fossils. Although a number of specimens were found, they were so badly disintegrated by the crystallization of gypsum and the weathering of marcasite that they were not worth collecting.

About 70 specimens, representing 20 genera, were obtained in the Boysen Reservoir area. Although the specimens were for the most part rather fragmentary, they were sufficiently well preserved to establish the age of those beds as belonging to the Lost Cabin faunal zone of the lower Eocene, a fact that had not previously been demonstrated. In the material obtained is the most nearly complete skull yet found of the primitive insectivore, *Didelphodus*. Although badly crushed and not impressive to look at, it adds a number of previously unknown details to the knowledge of the cranial morphology of that form. Also the skull and jaws of *Didymictis*, a primitive carnivore a little larger than a fox, was obtained in that area. Heretofore the form was known only from upper and lower dentitions.

Nearly 125 specimens, principally insectivores, rodents, and small artiodactyls, were obtained in the Canyon Ferry Reservoir area. Most of the specimens were found in the Oligocene deposits which previously were very poorly known. The material obtained demonstrated that deposits of both lower and middle Oligocene age were present in that area. One of the Oligocene insectivores belongs to a problematical family previously unknown in deposits later than the upper Eocene. Also, it is the best-preserved specimen yet found and adds many details of the skull and dentition to the knowledge of that group. The small Oligocene mammals of that area, when compared

to those of the same age on the Plains, illustrate the principles of geographical variation quite as well as the living species.

White's laboratory activities for the year fall into two periods. The first, from October 4 to November 5, was spent at the field office at Lincoln, Nebr., preparing supplementary reports on the reservoirs visited and in identifying the osteological material obtained in archeological excavations. Also, during that period the first draft of the technical report on the physiographic studies in the Angostura area was prepared. The remaining time was spent in the division of vertebrate paleontology at the United States National Museum. In addition to the preparation of technical reports on the paleontological material obtained in the reservoir areas, six boxes of osteological material from the Missouri and Columbia Basins were identified.

White completed two technical reports representing the results of field and laboratory activities. They are: "Preliminary Analysis of the Vertebrate Fossil Fauna of the Boysen Reservoir Area," and "Endocrine Glands and Evolution No. 2: The Appearance of Large Amounts of Cement on the Teeth of Horses." Both were submitted for publication. At the close of the year he had virtually finished two other papers: "A Preliminary Appraisal of the Physiographic History of Horsehead Creek in the Vicinity of 39FA65" (with Jack T. Hughes), and "Analysis of the Vertebrate Fossil Fauna of the Canyon Ferry Reservoir Area."

Throughout the field season White enjoyed congenial relationships with members of other Government agencies and with members of educational institutions. Among those from whom material assistance was received are: Harry A. Tourtelot of the United States Geological Survey, J. LeRoy Kay of the Carnegie Museum, Mr. McQuiren, geologist for the Bureau of Reclamation at the Boysen project, and Roy Austin, Superintendent of Public Schools at Townsend, Mont. Also the work was materially expedited by the many forest rangers who placed the facilities of their stations at the convenience of the party.

As in previous years, a number of student assistants were employed as members of the various field parties. Robert L. Hall and Warren L. Wittry were with the Cooper party from July 1 to September 4 and August 14, respectively. Gordon F. McKenzie joined the same party on August 1 and remained with it until September 4. John C. Donohoe was with the White party July 1 to 31, while Ernest L. Lundelius, Jr., accompanied it from July 1 to September 4. Dorothy E. Fraser was with the Cooper party during the month of August in the capacity of a special consultant. Neil J. Isto joined the Wheeler party on June 2 and was in the field at the close of the year.

Oklahoma.—Work in Oklahoma consisted of both surveys and

excavation. At the beginning of the year David J. Wenner, Jr., field assistant, was making a reconnaissance of the area to be flooded by the Tenkiller Ferry Reservoir on the Illinois River in the eastern part of the State. That work was completed on July 27 and the party moved to the Canadian Reservoir project on the Canadian River. Reconnaissance of that area was finished on August 17, when attention was turned to the adjacent Onapa project on the North Canadian. The survey there was completed on September 3. Within the 3 basins, 104 sites were found, 38 in Tenkiller Ferry, 41 in the Canadian, and 25 in Onapa. The work in Tenkiller Ferry demonstrated that what were presumed to be mounds, actually are natural knolls on flood plains and terraces, and all the sites present are village or camp remains. Those in the other two areas are also mainly village sites representing both historic and prehistoric cultures. In passing it should be stated that the Canadian and Onapa are two of three smaller alternate projects proposed to take the place of the larger Eufaula Reservoir. The third in the group, the Gaines, still remains to be surveyed. Should the single Eufaula project eventually be carried through instead of the three smaller ones, very little additional field work will be required to determine the archeological manifestations involved. It is known that there are a number of mounds that lie outside the boundaries of the smaller reservoirs but which would fall within the maximum pool of the Eufaula. Mr. Wenner was aided in his work by William Mayer-Oakes and Robert Shalkop, student assistants.

The excavations were at the Norman site in the Fort Gibson Reservoir basin on the Grand (Neosho) River near Wagoner. Earlier work by the University of Oklahoma had shown that the extensive village and mound group located there belonged to a Spiro-type culture and raised the possibility that the flooding of the largest double mound, which had never been excavated, would represent the loss of as important information and material as had the destruction of the famous Spiro mounds in the adjacent county. When Dr. Robert E. Bell of the Department of Anthropology of the University of Oklahoma reached the site in July he found that nearly all the village area and all mounds, with the exception of the largest double unit, had been removed by the bulldozers of the construction contractor. Even the large double unit had been damaged. The western periphery had been cut away and the smaller mound had been cut down several feet. With the assistance of the Engineers Dr. Bell was able to stop the operations so that archeological work could be done. During July and the first 2 weeks in August the University of Oklahoma field session under Bell excavated portions of several house sites still surviving south of the larger mound. On

August 17, under the sponsorship of the River Basin Surveys, he began excavation of the large double mound by cutting a trench across the saddle between the two parts of the unit. The southern face of the trench was then carried forward toward the larger mound. Joseph R. Caldwell joined Bell on August 19 and they decided that neither the available time nor funds would permit the customary method of cutting forward with a continuous vertical face. Accordingly, a 10-foot trench was driven through the north-south axis of the mound to reach its base and to obtain a complete profile. The work continued until September 22. Surprisingly, the mound yielded very few specimens. Potsherds and artifacts were scarce throughout its various levels. It was learned, however, that its main portion was composed of six superimposed platforms which probably had been the placements for public buildings, although no complete post-hole patterns were discovered. The summit of the fifth stage above the base had been divided into two nearly equal areas by a single row of posts, and the entire level gave evidence of a severe conflagration in prehistoric times. Four human burials were found in the top level, but they were in such an advanced stage of decomposition that little remained to indicate their character. A number of glass beads in the same level suggests a historic contact in the final days of occupation. The results of the digging indicated that no additional work was required at the Norman site. During the course of the investigations there, however, another site was located which appears to be an important one, and it was recommended that further efforts in the Fort Gibson area be concentrated there.

Red River of the North Basin.—Between August 27 and October 29, 1948, Richard P. Wheeler, archeologist, investigated four Corps of Engineers reservoir areas in the Red River of the North Drainage Basin: the Homme Reservoir, under construction on the South Branch of the Park River, the proposed Pembina River and Tongue River Reservoirs, in northeastern North Dakota; and the proposed Orwell Reservoir, on the Ottertail River, in west-central Minnesota. In reports on those surveys, prepared at the Lincoln office of the River Basin Surveys between November 5 and 19 and issued at Washington, D. C., in December 1948, Wheeler noted the occurrence of sites in the vicinity of the Homme and Orwell Reservoirs but recorded the discovery of only one archeological site in the reservoir areas proper, an occupation site in the Pembina River Reservoir. The finding of bison bones in all four of the reservoir areas indicates that the river valleys were formerly the habitat of bison and perhaps of other large game and were possibly visited by hunting bands in prehistoric and historic times. It was recommended that rechecks be made at the Homme Reservoir, following the clearing of timber and underbrush,

and at the Pembina River and Orwell Reservoirs, at the time of the construction of the dams, in order to make sure that no archeological remains were overlooked.

Texas.—The River Basin Surveys continued to operate throughout the year from the base and headquarters supplied by the Department of Anthropology at the University of Texas, Austin, Tex. Surveys were begun and carried to completion in five Corps of Engineers reservoirs.

Robert L. Stephenson, archeologist, left Austin at the beginning of the fiscal year and went to Fort Worth where he conferred with the Engineer in Charge, Fort Worth Suboffice, Corps of Engineers, preparatory to starting surveys of four reservoir basins on the upper branches of the Trinity River.

During July he completed investigations at the Benbrook Reservoir on the Clear Fork of the Trinity River in Tarrant County and at the Grapevine Reservoir on Denton Creek in Tarrant and Denton Counties. No sites were found in the Benbrook basin and only 10, none of which require further investigation, were noted at Grapevine. In addition he made a 2-day reconnaissance in the areas of the Lavon Reservoir on the East Fork of the Trinity River and Garza-Little Elm Reservoir on the Elm Fork of the same stream. On the latter trip R. K. Harris, Rex Housewright, and Lester Wilson, of the Dallas Archeological Society, took him to sites that they had previously located in the two areas.

On August 1, Mr. Stephenson accompanied Drs. Gustav A. Cooper and A. R. Loeblich, Jr., of the United States National Museum, and Robert Stark of Grapevine, Tex., to the vicinity of Bridgeport, Wise County, to collect invertebrate fossils. He also visited the Whitney Reservoir on the Brazos River, Hill County, and collected mollusks, needed to check previous identifications, from several archeological sites. From there he went to the Texarkana Reservoir on the Sulphur River, Bowie County, for the purpose of gathering information regarding the dates of construction and of determining the necessary time and extent of a survey for that basin. During the month he also completed an intensive survey of the Garza-Little Elm basin where he noted 27 sites, 7 of which were recommended for further examination, and started investigations at the Lavon project. The latter continued until September 17 and during the progress of the work he made test excavations at two sites. The survey located 25 sites, of which 8 have been recommended for more intensive investigations. Both in the excavations and the survey he was greatly assisted by the members of the Dallas Archeological Society and on September 10 spoke before a meeting of that organization. On September 18 he started a survey of the San Angelo Reservoir area on the North Concho

River in Tom Greene County, which was finished on October 10. Only 13 small sites were located there, and as similar material is available elsewhere no further work was recommended for the basin.

Except for several short trips, Mr. Stephenson spent the remainder of the fiscal year at the headquarters in Austin analyzing the material collected and preparing reports on the summer's surveys. He went to Lincoln, Nebr., in November for the purpose of studying the field and laboratory methods being used by the Missouri Basin group and while there attended sessions of the Sixth Conference for Plains Archeology and was appointed to the Committee on Archeological Nomenclature. From January 2 to 7, he revisited the upper Trinity River area to investigate reports of additional material having been found there. Papers prepared by Stephenson during the months in the laboratory are: "Archeological Survey of McGee Bend Reservoir," which was published in volume 19 of the Bulletin of the Texas Archeological and Paleontological Society; "Archeological Survey of the Lavon and Garza-Little Elm Reservoirs," to be published in volume 20 of the same journal; "A Note on Some Large Pits in Certain Sites near Dallas, Texas," printed in *American Antiquity*, vol. 15, No. 1; a revision of his earlier report on the Whitney Reservoir which was mimeographed and distributed by the Washington office in April; and preliminary appraisals on the Benbrook, Grapevine, Garza-Little Elm, and San Angelo surveys. He also wrote a summary statement covering the results of the River Basin Surveys from their inception in 1947 to June 30, 1949, and prepared a summary and table of the culture sequences and their relationships in the Texas area as they had been worked out up to that date.

Results of the year's investigations established a number of facts. In the survey of the Garza-Little Elm basin it was found that the remains include key sites for the determination of the cultural sequences in the area east of that known to have been inhabited by groups classified as the Henrietta Focus and west of the known Caddoan area. Similar sites have not been observed elsewhere. Very little is known of the cultural sequences involved in the area drained by the three forks of the Trinity River. The eight sites in the Lavon basin recommended for more intensive examination are believed to hold the answer to the problem of developments in the western border of the Caddo area. At least one new culture remains to be defined and described from the excavation of those sites. Furthermore, the material from them should shed much light on the interrelation between the cultures represented there and those to the east and west.

Cooperating institutions.—Numerous State and local institutions cooperated with the River Basin Surveys throughout the year and made a definite contribution to the progress of the program. The

Universities of Nebraska, Oklahoma, Oregon, and Texas provided space for field offices and laboratories for regular units of the Surveys, while the Universities of Denver, Colorado, and California, and Western State College of Colorado supplied temporary bases of operations for specific projects. The Universities of California, Oklahoma, Oregon, and Washington joined forces with the Surveys for some reconnaissance work and for the excavations at the Fort Gibson, McNary, and O'Sullivan Reservoirs. In a number of cases responsibility for units in the survey and excavation program was assumed by State and local institutions.

The Museum of Northern Arizona and the University of Arizona did some preliminary survey work, while the San Diego Museum of Man conducted surveys and did some digging in the area of the Davis Dam on the Colorado River between Arizona and Nevada. The University of Arkansas engaged in both reconnaissance and excavations in the area of Bull Shoals Reservoir in that State. The California Archeological Survey of the University of California conducted excavations at the Pine Flat and Isabella Reservoirs, while the Archeological Surveys Association of Southern California carried on reconnaissance work in that part of the State. The Florida Park Service surveyed the section in northern Florida that will be affected by the Jim Woodruff Dam on the Apalachicola River near Chattahooche and did some digging in a number of sites. The University of Georgia continued its surveys along the Chattahooche and Flint Rivers and conducted excavations at one site in the Allatoona Reservoir on the Etowah River. In Illinois the University of Illinois, the University of Chicago, and the Illinois State Museum furnished information about the extent and character of sites in the basins of 15 reservoir projects proposed for the Illinois River drainage. The Indiana Historical Bureau carried on surveys and did some excavating not only at proposed Federal projects, but at those under State construction as well.

The Museum of Natural History of the University of Kansas made excavations at Kanopolis Reservoir in July and August of 1948 in sites where the rising waters of the reservoir were already encroaching upon the remains. The results of that work were reported on by Dr. Carlyle S. Smith in an article, "Archeological Investigations in Ellsworth and Rice Counties, Kansas," which appeared in *American Antiquity*, vol. 14, No. 4, April 1949. In June of 1949 the same institution was beginning investigations at the Glen Elder Reservoir with other work planned for the Woodston, Webster, and Cedar Bluff projects in the same region of the Solomon River drainage. In Kentucky the University continued its program of excavations at the Wolf Creek Reservoir on the Cumberland River and at the Dewey

Reservoir on Johns Creek. The University of Missouri and the Missouri Archeological Society again cooperated in making surveys in a number of reservoirs and in excavating sites in the Missouri portion of the Bull Shoals Reservoir and in the Clearwater and Pomme de Terre basins on the Black and Pomme de Terre Rivers, respectively. At the end of the year Montana State University was starting field work at the Canyon Ferry Reservoir on the Missouri River near Townsend, Mont.

The Laboratory of Anthropology of the University of Nebraska was excavating in sites at the Harlan County Reservoir on the Republican River in the southern part of the State at the start of the fiscal year and had returned to the same locality for further activities in June 1949. The work done during the summer of 1948 was described by Dr. John L. Champe, in a report, "White Cat Village," published in *American Antiquity*, vol. 14, No. 4, April 1949. The Nebraska State Historical Society excavated a number of sites in the Medicine Creek Reservoir area in the early months of the year and in June had a party digging in the Mullen Reservoir area on the Middle Loup River in the north-central part of the State. The University of Nebraska State Museum continued its paleontological and archeological investigations in the Harlan County and Medicine Creek Reservoir areas. One site in the Medicine Creek basin that proved of particular interest because of its implications of considerable antiquity was described in an article, "The Frontier Culture Complex, a Preliminary Report on a Prehistoric Hunter's Camp in Southwestern Nebraska," written by Preston Holder and Joyce Wike and printed in *American Antiquity*, vol. 14, No. 4, April 1949.

The University of North Dakota and the North Dakota Historical Society cooperated in excavations at the Baldhill Reservoir in the eastern part of the State in the summer of 1948, and toward the close of the fiscal year were preparing for intensive survey work in the Garrison Reservoir on the Missouri River near Sanish, N. Dak. The results of the previous summer's work were discussed by Dr. Gordon W. Hewes in "Burial Mounds in the Baldhill Area, North Dakota," which appeared in the April 1949 issue of *American Antiquity*, vol. 14, No. 4. The Ohio State Museum did some survey and excavation work. The University of Oklahoma, as previously mentioned, did some digging at the Fort Gibson Reservoir and made independent surveys in other areas. The University of Utah assumed responsibility for surveys at a number of projects in the southwestern corner of that State but at the close of the year had not yet started field work. In Wisconsin, Beloit College made surveys and did some digging in the Black River project.

The various cooperating organizations send progress and completed reports to the River Basin Surveys so that the results of their work may be coordinated with those for the over-all program. In this way the information obtained by them becomes a part of the general record of the River Basin Surveys.

EDITORIAL WORK AND PUBLICATIONS

There were issued one Annual Report and two Publications of the Institute of Social Anthropology as listed below:

Sixty-fifth Annual Report of the Bureau of American Ethnology, 1947-1948. 32 pp.

Institute of Social Anthropology Publ. No. 8. Sierra Popoluca speech, by Mary L. Foster and George M. Foster. 45 pp.

Institute of Social Anthropology Publ. No. 9. The Terena and the Caduveo of southern Mato Grosso, Brazil, by Kalervo Oberg. 72 pp., 24 pls., 4 maps, 2 charts.

The following publications were in press at the close of the fiscal year:

Bulletin 143. Handbook of South American Indians. Julian H. Steward editor. Volume 5, The comparative ethnology of South American Indians. Volume 6, Physical anthropology, linguistics, and cultural geography of South American Indians.

Miscellaneous publications. List of publications of the Bureau of American Ethnology, with index to authors and titles. Revised to July 30, 1949.

Bulletin 144. The Northern and Central Nootkan tribes, by Philip Drucker.

Institute of Social Anthropology Publ. No. 10. Nomads of the long bow: The Siriono of eastern Brazil, by Allan R. Holmberg.

Institute of Social Anthropology Publ. No. 11. Quiroga: A Mexican Municipio, by Donald D. Brand.

Institute of Social Anthropology Publ. No. 12. Cruz das Almas: A Brazilian village, by Donald Pierson.

Publications distributed totaled 19,660, as compared with 25,037 for the fiscal year 1948.

LIBRARY

Accessions in the library totaled 112 volumes, bringing the total accession record as of June 30, 1949, to 34,719.

ILLUSTRATIONS

During the entire year the work of restoration on the valuable collection of old Indian photographs was continued. Approximately 150 restorations were completed.

The remainder of the time of the illustrator and of his assistant was spent on the regular work of preparation of illustrations and maps for Bureau publications.

ARCHIVES

Research workers and students continued to use the manuscript material and the archives both through personal visits for consultation and by correspondence. A number of manuscripts on the various Iroquoian tribes were loaned to the Library of the American Philosophical Society, Philadelphia, for use of students and research workers in that field. The major task of carding the more important Indian vocabularies has been begun with Indian and English divisions for each. These vocabularies are being arranged so that they can be expanded as new material arrives. Many of the Iroquoian vocabularies collected by James Mooney, Erminnie Smith, and J. N. B. Hewitt, as well as a Natchez vocabulary collected by A. S. Gatchet, have been carded.

Some 5,000 prints and negatives, including both black and white and color, have been made during the year for various purposes. Considerable use was made during the fiscal year of the photographic collections as illustrations for both scientific and commercial purposes. The Walt Disney Studio and Metro-Goldwyn-Mayer have consulted the photographic files for authentic material in making motion pictures dealing with Indian subjects.

COLLECTIONS

Acc. No.

- 1 lot of fossils collected by Dr. Theodore E. White, Ernest L. Lundelius, and John C. Donohoe, from 6 locations in the Boysen Reservoir area, Wyoming. River Basin Surveys.
- 1 lot of fossils collected by Theodore E. White, Ernest L. Lundelius, and John C. Donohoe, from 5 localities within the Canyon Ferry Reservoir area, near Helena, Mont. River Basin Surveys.
- 181, 218 1 lot of earthenware vessels and other artifacts collected by Dr. Gordon R. Willey in Virú Valley, Department of La Libertad, Perú.
- 182, 450 24 hand-made silver brooches from the Grand River Indians at Caledonia, Ontario, Canada. Bought by the Bureau from Ephraim Schuyler, Oneida, Wis.
- 182, 928 1 tobacco pouch and pipe of White Calf, a former chief of the Blackfoot Indians. Bequeathed by Florence Merriam Bailey to the Bureau.
- 182, 986 1 lot of potsherds collected from Pissaisac, an Algonquian village, near Leedstown, Va., by the late David I. Bushnell, Jr.
- 179, 533 1 lot of archeological material collected at the Hodges site on Plaza Larga Creek, Quay County, N. Mex., in August 1947 by Herbert W. Dicks as a project of the River Basin Surveys.
- 179, 773 Indian skeleton from Lake Spring site, Savannah River, Georgia. River Basin Surveys.
- 180, 455 1 lot of stone artifacts and rejectage collected by Sheldon Judson at various sites in Clay County, N. Mex.

Acc. No.

- 1 lot of stone artifacts and potsherds collected by Drs. M. W. Stirling and Gordon R. Willey from a prehistoric shell mound near Monagrillo, Herrera Province, Republic of Panamá, during the 1948 Smithsonian Institution-National Geographic Society Expedition to Panamá.

MISCELLANEOUS

During the year Miss Frances Densmore, Dr. John R. Swanton, and Dr. Antonio J. Waring, Jr., continued as collaborators of the Bureau of American Ethnology.

During the course of the year information was furnished by members of the Bureau staff in reply to numerous inquiries concerning the American Indians of both continents, past and present. Various specimens sent to the Bureau were identified and data on them furnished for their owners.

Respectfully submitted.

M. W. STIRLING, *Director.*

Dr. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE INTERNATIONAL EXCHANGE SERVICE

SIR: I have the honor to submit the following report on the activities of the International Exchange Service for the fiscal year ended June 30, 1949.

The Smithsonian Institution is the official United States agency for the exchange with other nations of governmental, scientific, and literary publications. The International Exchange Service, initiated by the Smithsonian Institution in the early years of its existence for the interchange of scientific publications between learned societies and individuals in the United States and those of foreign countries, serves as a means of developing and executing in part the broad and comprehensive object, "the diffusion of knowledge." It was later designated by the United States Government as the agency for the transmission of official documents to selected depositories throughout the world, and it continues to execute the exchanges pursuant to conventions, treaties, and other international agreements.

The number of packages received for transmission during the year was 840,125, an increase over the previous year of 80,006. The weight of these packages was 796,700 pounds, a decrease of 15,489 pounds. The average weight of the individual package is approximately 15 ounces, as compared with the average of the previous year of 1 pound, 1 ounce—an indication that the various institutions have almost completed shipment of the material that was held during the war. The material received from both foreign and domestic sources for shipment is classified as shown in the following table:

Classification	Packages		Weight	
	<i>Number</i>	<i>Number</i>	<i>Pounds</i>	<i>Pounds</i>
United States parliamentary documents sent abroad.....	395,696		169,644	
Publications received in return for parliamentary documents.....		10,019		17,123
United States departmental documents sent abroad.....	194,080		185,669	
Publications received in return for departmental documents.....		4,784		12,037
Miscellaneous scientific and literary publications sent abroad.....	206,887		346,532	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States.....		28,659		65,695
Total.....	796,663	43,462	701,845	94,855
Grand total.....	840,125		796,700	

The packages are forwarded either by mail direct to the addresses or by freight to the exchange bureaus of foreign countries. The number of boxes shipped to the foreign exchange bureaus was 3,296, an increase of 189 over the previous year. Of the boxes shipped 650 were for depositories of full sets of United States Government documents furnished in exchange for the official publications of foreign governments for deposit in the Library of Congress. The number of packages forwarded by mail was 155,402.

In spite of the fact that considerable savings in transportation continued to be effected by exporting from Baltimore rather than New York, and in spite of the advantage gained through special arrangements for shipments to Germany, the allotment for transportation was practically exhausted by the end of May 1949. Therefore, it was necessary to curtail shipments sharply during the last month of the fiscal year, and this resulted in a backlog of approximately 146,000 pounds.

Consignments are now forwarded to all countries except Rumania, and efforts are continued to effect exchanges with that country.

FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

The number of sets of United States official publications received by the Exchange Service to be sent abroad in return for the official publications sent by foreign governments for deposit in the Library of Congress is 96 (58 full and 38 partial sets). The Government Book Depot, Rangoon, has been added to the list of full depositories.

DEPOSITORIES OF FULL SETS

ARGENTINA: Dirección de Investigaciones, Archivo, Biblioteca y Legislación Extranjero, Ministerio de Relaciones Exteriores y Culto, Buenos Aires.

AUSTRALIA: Commonwealth Parliament and National Library, Canberra.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

QUEENSLAND: Parliamentary Library, Brisbane.

SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.

TASMANIA: Parliamentary Library, Hobart.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

AUSTRIA: Administrative Library, Federal Chancellery, Vienna.¹

BELGIUM: Bibliothèque Royale, Bruxelles.

BRAZIL: Instituto Nacional do Livro, Rio de Janeiro.

BULGARIA: Bulgarian Bibliographical Institute, Sofia.

BURMA: Government Book Depot, Rangoon.²

CANADA: Library of Parliament, Ottawa.

MANITOBA: Provincial Library, Winnipeg.

ONTARIO: Legislative Library, Toronto.

QUEBEC: Library of the Legislature of the Province of Quebec.

¹ Changed from National Library of Austria.

² Added during year.

CHILE: Biblioteca Nacional, Santiago.

CHINA: Ministry of Education, National Library, Nanking, China.³

PEIPING: National Library of Peiping.

COLOMBIA: Biblioteca Nacional, Bogotá.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CUBA: Ministerio de Estado, Canje Internacional, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.

DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.

EGYPT: Bureau des Publications, Ministère des Finances, Cairo.

FINLAND: Parliamentary Library, Helsinki.

FRANCE: Bibliothèque Nationale, Paris.

GERMANY: Öffentliche Wissenschaftliche Bibliothek, Berlin.

American Institut, Berlin.^{3 4}

GREAT BRITAIN:

ENGLAND: British Museum, London.

LONDON: London School of Economics and Political Science. (Depository of the London County Council.)

HUNGARY: Library of Parliament, Budapest.

INDIA: National Library, Calcutta.

IRELAND: National Library of Ireland, Dublin.

ITALY: Ministero della Pubblica Istruzione, Rome.

JAPAN: National Diet Library, Tokyo.⁵

MEXICO: Secretaría de Relaciones Exteriores, Departamento de Información para el Extranjero, Mexico, D. F.

NETHERLANDS: Royal Library, The Hague.

NEW ZEALAND: General Assembly Library, Wellington.

NORTHERN IRELAND: H. M. Stationery Office, Belfast.

NORWAY: Utenriksdepartementets Bibliothek, Oslo.⁶

PERU: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.

PHILIPPINES: Bureau of Public Libraries, Department of Education, Manila.⁷

POLAND: Bibliothèque Nationale, Warsaw.

PORTUGAL: Biblioteca Nacional, Lisbon.

RUMANIA: Academia Română, Bucharest.⁸

SPAIN: Cambio Internacional de Publicaciones, Avenida Calvo Sotelo 20, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.

TURKEY: Department of Printing and Engraving, Ministry of Education, Istanbul.

UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.

UNION OF SOVIET SOCIALIST REPUBLICS: All-Union Lenin Library, Moscow 115.

UKRAINE: Ukrainian Society for Cultural Relations with Foreign Countries, Kiev.⁸

UNITED NATIONS: Library of the United Nations, Geneva, Switzerland.

URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.

VENEZUELA: Biblioteca Nacional, Caracas.

YUGOSLAVIA: Ministère de l'Education, Belgrade.

³ Suspended.

⁴ Held for disposition by Library of Congress.

⁵ Changed from National Library of Japan.

⁶ Changed from Universitets-Bibliothek.

⁷ Changed from National Library.

⁸ Suspended.

DEPOSITORIES OF PARTIAL SETS

AFGHANISTAN: Library of the Afghan Academy, Kabul.

BOLIVIA: Biblioteca del Ministerio de Relaciones Exteriores y Culto, La Paz.

BRAZIL:

MINAS GERAES: Directoria Geral de Estatística em Minas, Belo Horizonte.

BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.

CANADA:

ALBERTA: Provincial Library, Edmonton.

BRITISH COLUMBIA: Provincial Library, Victoria.

NEW BRUNSWICK: Legislative Library, Fredericton.

NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.

SASKATCHEWAN: Legislative Library, Regina.

CEYLON: Department of Information, Government of Ceylon, Colombo.⁹

DOMINICAN REPUBLIC: Biblioteca de la Universidad de Santo Domingo, Ciudad Trujillo.

ECUADOR: Biblioteca Nacional, Quito.

GREECE: National Library, Athens.

GUATEMALA: Biblioteca Nacional, Guatemala.

HAITI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS:

Biblioteca y Archivo Nacionales, Tegucigalpa.

Ministerio de Relaciones Exteriores, Tegucigalpa.

ICELAND: National Library, Reykjavik.

INDIA:

BIHAR AND ORISSA: Revenue Department, Patna.

BOMBAY: Undersecretary to the Government of Bombay, General Department, Bombay.

UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.

WEST BENGAL: Library, West Bengal Legislature, Assembly House, Calcutta.

IRAN: Imperial Ministry of Education, Tehran.

IRAQ: Public Library, Baghdad.

JAMAICA: Colonial Secretary, Kingston.

LIBERIA: Department of State, Monrovia.

MALAYA: Federal Secretariat, Federation of Malaya, Kuala Lumpur.¹⁰

MALTA: Minister for the Treasury, Valleta.

NEWFOUNDLAND: Department of Home Affairs, St. John's.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

PAKISTAN: Chief Secretary to the Government of Punjab, Lahore.

PANAMA: Ministerio de Relaciones Exteriores, Panama.

PARAGUAY: Ministerio de Relaciones Exteriores Sección Biblioteca, Asunción.

SALVADOR:

Biblioteca Nacional, San Salvador.

Ministerio de Relaciones Exteriores, San Salvador.

SIAM: National Library, Bangkok.

SINGAPORE: Chief Secretary, Government Offices, Singapore.¹⁰

VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City, Italy.

⁹ Changed from Chief Secretary's Office, Record Department of the Library.

¹⁰ Added during year.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

There are now being sent abroad 81 copies of the Federal Register and 75 copies of the Congressional Record. This is an increase of 8 copies of the Federal Register and 9 of the Congressional Record over the preceding year. The countries to which these journals are being forwarded are given in the following list:

DEPOSITORIES OF CONGRESSIONAL RECORD AND FEDERAL REGISTER

ARGENTINA:

- Biblioteca del Congreso Nacional, Buenos Aires.
- Biblioteca del Poder Judicial, Mendoza.¹¹
- Cámara de Diputados, Oficina de Información Parlamentaria, Buenos Aires.
- Boletín Oficial de la República Argentina, Ministerio de Justicia e Instrucción Pública, Buenos Aires.

AUSTRALIA:

- Commonwealth Parliament and National Library, Canberra.
- NEW SOUTH WALES: Library of Parliament of New South Wales, Sydney.
- QUEENSLAND: Chief Secretary's Office, Brisbane.
- WESTERN AUSTRALIA: Library of Parliament of Western Australia.

BRAZIL:

- Biblioteca da Camera dos Deputados, Rio de Janeiro.¹²
- Imprensa Nacional, Rio de Janeiro.¹¹
- AMAZONAS: Archivo, Biblioteca e Imprensa Publica, Manáos.
- BAHIA: Governador do Estado da Bahia, São Salvador.
- ESPIRITO SANTO: Presidencia do Estado do Espirito Santo, Victoria.
- RIO GRANDE DO SUL: Imprensa Oficial do Estado, Porto Alegre.
- SERGIPE: Biblioteca Publica do Estado de Sergipe, Aracajú.
- SÃO PAULO: Imprensa Oficial do Estado, São Paulo.

BRITISH HONDURAS: Colonial Secretary, Belize.

CANADA:

- Library of Parliament, Ottawa.
- Clerk of the Senate, Houses of Parliament, Ottawa.

CUBA:

- Biblioteca del Capitolio, Habana.
- Biblioteca Publica Panamericana, Habana.¹³
- House of Representatives, Habana.¹⁴

EGYPT: Ministry of Foreign Affairs, Egyptian Government, Cairo.¹⁵

EL SALVADOR: Library, National Assembly, San Salvador.

FRANCE:

- Bibliothèque Assemblée Nationale, Paris.¹⁶
- Bibliothèque, Conseil de la République.
- Publiques de l'Institut de Droit Compare, Université de Paris, Paris.¹¹
- Service de la Documentation Etrangère, Assemblée Nationale, Paris.^{13 14}

¹¹ Federal Register only.

¹² Changed from Biblioteca do Congresso Nacional.

¹³ Congressional Record only.

¹⁴ Added during year.

¹⁵ Changed from Bibliothèque, Chambre des Députés.

GERMANY: Der Bayrische Landtag, Munich.^{16 17}

GREAT BRITAIN:

House of Commons Library, London.^{16 17}

Printed Library of the Foreign Office, London.

GREECE: Library, Greek Parliament, Athens.

GUATEMALA: Biblioteca de la Asamblea Legislativa, Guatemala.

HAITI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.

INDIA:

Civil Secretariat Library, Lucknow, United Provinces.¹⁸

Legislative Assembly Library, Lucknow, United Provinces.

Legislative Department, Simla.

INDONESIA: Provisional Parliament of East-Indonesia, Macassar, Celebes.¹⁷

IRELAND: Dail Eireann, Dublin.

ITALY:

Biblioteca Camera dei Deputati, Rome.¹⁷

Biblioteca del Senato della Repubblica, Rome.¹⁷

European Office, Food and Agriculture Organization of the United Nations, Rome.^{17 18}

International Institute for the Unification of Private Law, Rome.¹⁸

MEXICO:

Dirección General de Información, Secretaría de Gobernación, Mexico, D. F.

Biblioteca Benjamin Franklin, Mexico, D. F.

AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.

CAMPECHE: Gobernador del Estado de Campeche, Campeche.

CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Gutierrez.

CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.

COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.

COLIMA: Gobernador del Estado de Colima, Colima.

DURANGO: Gobernador Constitucional del Estado de Durango, Durango.

GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.

GUERRERO: Gobernador del Estado de Guerrero, Chilpancingo.

JALISCO: Biblioteca del Estado, Guadalajara.

LOWER CALIFORNIA: Gobernador del Distrito Norte, Mexicali.

MÉXICO: Gaceta del Gobierno, Toluca.

MICHOACÁN: Secretaría General de Gobierno del Estado de Michoacán, Morelia.

MORELOS: Palacio de Gobierno, Cuernavaca.

NAYARIT: Gobernador de Nayarit, Tepic.

NUEVO LEÓN: Biblioteca del Estado, Monterrey.

OAXACA: Periódico Oficial, Palacio de Gobierno, Oaxaca.

PUEBLA: Secretaría General de Gobierno, Puebla.

QUERÉTARO: Secretaría General de Gobierno, Sección de Archivo, Querétaro.

SAN LUIS POTOSÍ: Congreso del Estado, San Luis Potosí.

SINALOA: Gobernador del Estado, de Sinaloa, Culiacán.

SONORA: Gobernador del Estado de Sonora, Hermosillo.

TABASCO: Secretaría de Gobierno, Sesión 3a, Ramo de Prensa, Villahermosa.

¹⁶ Congressional Record only.

¹⁷ Added during year.

¹⁸ Federal Register only.

MEXICO—Continued

TAMAULIPAS: Secretaría General de Gobierno, Victoria.

TLAXCALA: Secretaría de Gobierno del Estado, Tlaxcala.

VERACRUZ: Gobernador del Estado de Veracruz, Departamento de Gobernación y Justicia, Jalapa.

YUCATÁN: Gobernador del Estado de Yucatán, Mérida.

NETHERLANDS: Koninklijke Bibliotheek, The Hague.^{19 20}

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Library of the Norwegian Parliament, Oslo.¹⁹

PERU: Cámara de Diputados, Lima.

POLAND: Ministry of Justice, Warsaw.²⁰

SPAIN: Diputación de Navarra, San Sebastian.

SWITZERLAND: Bibliothèque, Bureau International du Travail, Geneva.²⁰

Library, United Nations, Geneva.¹⁹

UNION OF SOUTH AFRICA:

CAPE OF GOOD HOPE: Library of Parliament, Cape Town.

TRANSVAAL: State Library, Pretoria.

URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.

VENEZUELA: Biblioteca del Congreso, Caracas.

FOREIGN EXCHANGE AGENCIES

Exchanges are sent to all countries except Rumania. The countries listed are those to which shipments are forwarded by freight. To other countries not appearing on the list, packages are forwarded by mail.

LIST OF AGENCIES

AUSTRIA: Austrian National Library, Vienna.

BELGIUM: Service des Échanges Internationaux, Bibliothèque Royale de Belgique, Bruxelles.

CHINA: Bureau of International Exchange, National Central Library, Nanking.

CZECHOSLOVAKIA: Bureau des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1-100.

DENMARK: Institut des Échanges Internationaux, Bibliothèque Royale, Copenhagen K.

EGYPT: Government Press, Publications Office, Bulaq, Cairo.

FINLAND: Delegation of the Scientific Societies of Finland, Kasärngatan 24, Helsinki.

FRANCE: Service des Échanges Internationaux, Bibliothèque Nationale, 58 Rue de Richelieu, Paris.

GERMANY: Öffentliche Wissenschaftliche Bibliothek, Berlin.^{21 22}

German Central Committee for Distribution of Cultural Materials, Stuttgart.^{21 22}

GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 83/84 Berwick Street, London, W. 1.

HUNGARY: Hungarian Libraries Board, Ferenciektere 5, Budapest, IV.

INDIA: Superintendent of Government Printing and Stationery, Bombay.

ITALY: Ufficio degli Scambi Internazionali, Ministero della Pubblica Istruzione, Rome.

¹⁹ Added during year.

²⁰ Federal Register only.

²¹ Distribution under supervision of Department of the Army.

²² For all sectors of Berlin and Russian Zone.

²³ For American, British, and French Zones.

JAPAN: International Exchange Service, National Library of Japan, Uyeno Park, Tokyo.²⁴

NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.

PALESTINE: Jewish National and University Library, Jerusalem.²⁴

PHILIPPINES: Bureau of Public Libraries, Department of Education, Manila.

POLAND: Service Polonais des Échanges Internationaux, Bibliothèque Nationale, Warsaw.

PORTUGAL: Secção de Trocas Internacionais, Biblioteca Nacional, Lisbon.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

RUMANIA: Ministère de la Propagande Nationale, Service des Échanges Internationaux, Bucharest.²⁵

SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.

SPAIN: Junta de Intercambio y Adquisición de Libros y Revistas para Bibliotecas Públicas, Ministerio de Educación Nacional, Avenida Calvo Sotelo 20, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Palais Fédérale, Berne.

TASMANIA: Secretary to the Premier, Hobart.

TURKEY: Ministry of Education, Department of Printing and Engraving, Istanbul.

UNION OF SOUTH AFRICA: Government Printing and Stationery Office, Cape Town, Cape of Good Hope.

UNION OF SOVIET SOCIALIST REPUBLICS: International Book Exchange Department, Society for Cultural Relations with Foreign Countries, Moscow, 56.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

YUGOSLAVIA: Section des Échanges Internationaux, Ministère des Affaires Étrangères, Belgrade.

Respectfully submitted.

D. G. WILLIAMS, *Chief.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

²⁴ Distribution under supervision of Department of the Army.

²⁵ Shipments suspended.

APPENDIX 7

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ended June 30, 1949.

The improved economic conditions were reflected in satisfactory developments at the Zoo during the year. The animal collection was gradually improved by obtaining rare or otherwise desirable animals to fill available cages, and personnel recruitment and training progressed satisfactorily, although it was not possible to fill all vacancies. With increased man power and more materials available, progress was made in taking care of the most needed repairs, and minor improvements were completed.

As of June 30, 1949, there were 3,724 specimens in the collection, an increase of 927 over the previous year. These represented 755 species, an increase of 65. Not only was the collection increased in size, but the quality was improved by the addition of animals that are not well known, thereby adding to its educational value.

The National Zoological Park renders a variety of services to the American public. Besides the animal exhibits and the providing of an attractive recreation area, valuable opportunities are offered for students of biology, particularly vertebrate zoology, as well as for artists, photographers, writers, and research workers—utilizing methods of research that do not endanger the welfare of the animals or of the public. Other direct services are answering in person, by phone, mail, and telegraph, questions regarding animals, their care and transportation; the furnishing of information to other zoos and private and public agencies regarding structures for keeping and housing animals; and cooperation with other agencies of the Federal, State, and municipal governments in research work.

THE EXHIBITS

Animals for the collection are acquired by gift, deposit, purchase, exchange, births and hatchings, and are removed by return of specimens on deposit, exchange, or death. Although depositors are at liberty to remove the specimens that they place in the Zoo, many leave the specimens for the rest of their lives.

As in any colony of living things, there is a steady turn-over, so that the exhibits are constantly changing. Thus, the inventory list of specimens in the collection on June 30 of each year does not show all the kinds of animals that were exhibited during the year; sometimes creatures of outstanding interest at the time they were shown are no longer in the collection at the time the list is prepared.

ACCESSIONS

A great many interesting shipments have been received from abroad. The Navy Medical Research Unit No. 3 sent through Lt. Robert E. Kuntz a large collection of Egyptian reptiles, including a number of species that the Zoo has never had before. The Institute of Scientific Research, Madagascar, sent by air a group of leopard chameleons, some *Zonosaurus* lizards, and two Dumeril's boas. The San Diego Zoological Society presented a beautiful specimen of the spectacled bear. The Army Medical Research Center Laboratory in Malaya sent through Maj. Robert Traub an interesting collection, including two striking bamboo rats and eight different species of tree rats, none of which had been exhibited heretofore. From the Zoological Society of London was received an extensive shipment, including 4 Chinese water deer, a kusimanse, some rare birds, and 2 of the rare Meller's chameleons.

Dr. Guillermo Mann of the University of Santiago, Santiago, Chile, sent specimens of Gay's frog and the unusual Bibron's "toad" frog, as well as three abrocomas, a rodent seldom seen in captivity. Pat Putnam sent from the Belgian Congo chameleons and francolins. Capt. John Miller of Panagra Airlines, Perú, shipped to the Zoo its first pair of the rare pigmy marmosets, smallest of all the monkeys.

Among the outstanding receipts through purchases or exchanges were an African two-horned rhinoceros, a pair of wombats, a king cormorant, a trio of kelp geese, orang-utans and chimpanzees. The latter are to replace the stock that some years ago was destroyed by an epidemic.

William T. Miller, after resigning from the Army, spent some time in Panamá and sent several shipments including a pigmy anteater and a great rufous motmot. Dr. A. Reventlow of the Zoological Garden at Copenhagen, Denmark, presented to the Zoo its first pair of whooper swans. From the Zoo in Rotterdam, Holland, were received a king cobra and some ruffs. In an air shipment from Australia came reptiles of more than a dozen species, including the carpet python, diamond python, and a number of rare lizards and turtles.

DEPOSITORS AND DONORS AND THEIR GIFTS

(Deposits are marked*)

Aiken, Jesse E., Chevy Chase, Md., opossum (young in pouch).
 Allen, Miss Joyce, Washington, D. C., sparrow hawk.
 Animal Rescue League, Washington, D. C., muskrat.
 Army Medical Research, Washington, D. C., slow loris.
 Arutsaw, Pvt. V. C., and Harp, Pvt. W. W., Washington, D. C., woodchuck.
 Ayars, James W., Silver Spring, Md., parrot.
 Balster, Joseph, Washington, D. C., festive parrot.
 Barbour, Charles, Sunnybrook, Md., fence lizard.
 Barker, J. M., Moyock, N. C., timber rattlesnake.
 Beck, L. V., Bethesda, Md., 2 zebra finches.
 Bernstein, Edward, Washington, D. C., white-throated capuchin.*
 Bittenbender, J. C., Arlington, Va., flying squirrel.
 Bitting, Maurice, Cheverly, Md., raccoon.
 Boswell, Mrs. May, Washington, D. C., green heron.
 Bowen, Mrs. Raymond J., Washington, D. C., mouse.
 Bratter, Miss J., Washington, D. C., Pekin duck.
 Brodess, Miss D., Washington, D. C., ring-necked dove.
 Brommer, K. M., Minneapolis, Minn., ferret.
 Burford, Captain, Falls Church, Va., opossum.
 Burke, Mrs. J. O., Washington, D. C., domestic white rabbit.
 Butler, H. M., Washington, D. C., alligator.
 Carrick, W. E., Capitol Heights, Md., skunk.
 Carroll, Robert, Arlington, Va., black widow spider.
 Carter, H. E., Alexandria, Va., ruby-throated humming bird.
 Catskill Game Farm, Inc., Catskill, N. Y., pigtail macaque monkey.
 Celia, Dominick, Bethesda, Md., sparrow hawk.
 Chamberlin, Donald, Kenwood, Md., sparrow hawk* and screech owl.*
 Claxen, Charles W., Chevy Chase, Md., 7 golden hamsters.
 Cliff, Miss Annie M., Bethesda, Md., Pekin duck.
 Collins, John F., Washington, D. C., 4 Pekin ducks.
 Colvin, Master E., Washington, D. C., red fox.
 Cook, Harry, Washington, D. C., alligator.
 Cool, Leon D., and Gascoyne, Rodney, Washington, D. C., whistling swan.*
 Coolidge, Belle, Washington, D. C., Pekin duck.
 Cooper, John, Washington, D. C., 2 raccoons.
 Coppel, Miss Marcia, Washington, D. C., Pekin duck.
 Corrigan, Miss Myrtle, Washington, D. C., painted bunting.
 Corver, H. O., Washington, D. C., opossum.
 Cunningham, J. Francis, Arlington, Va., 2 flying squirrels.
 Dale, Mr. and Mrs. Martin B., Arlington, Va., 3 grass parakeets (albino).
 Davis, L. W., Arlington, Va., 2 eastern skunks.
 Davis, Malcolm, Washington, D. C., American crow and 2 black vultures.
 Davis, Thomas M., Philadelphia, Pa., 3 Ameiva lizards, 8 blue honeycreepers,
 18 yellow atelopos.
 Decatur, Miss Edna, Washington, D. C., brown thrasher.
 Dent, W. W., Washington, D. C., ground hog.
 Denton, J. O., Alexandria, Va., skunk.
 Messrs. DePrato, Fiedler, and Davis, Washington, D. C., snapping turtle.
 Detmer, J., Washington, D. C., Pekin duck.

- Donovan, Daniel J., Washington, D. C., yellow-naped parrot.
 Douglas, F., Washington, D. C., raccoon.
 Douglas, Floyd G., (address unknown), American badger.
 Dour, John, Abington, Va., hog-nosed snake.
 DuBuy, Dr. H. G., Berwyn, Md., common goat.
 Dudley, Dr. A., Bethesda, Md., 5 opossums.
 Duetermann, Capt. W. V., Washington, D. C., Pekin duck.
 Dunning, Bill, Chevy Chase, Md., snapping turtle.
 Eleazec, J. M., Clemson, S. C., black vulture.
 Ellwanger, Mrs. Chas., Vienna, Va., screech owl.
 Ennes, Richard, Washington, D. C., 2 great horned owls.*
 Esfandiari, Mr., Washington, D. C., 6 white mice.
 Evans, Jim, (address unknown), hog-nosed snake and mole snake.
 Finely, Dr. H. E., Washington, D. C., bullfrog.
 Finnegan, Hugh L., Silver Spring, Md., 11 opossums.
 Flick, Carlton R., Mt. Rainier, Md., 5 opossums.
 Ford, Clifford, Shady Side, Md., spider monkey.
 Franciscan Monastery, Washington, D. C., bleeding-heart dove.
 Freret, Mrs. J. P., Alexandria, Va., flying squirrel.
 Friday, David L., Bethesda, Md., eastern gray squirrel.
 Gatti, Mrs. S. A., Washington, D. C., 2 grass parakeets, 2 Java sparrows, 9 canaries.
 Gilbert, Paul, Washington, D. C., double yellow-headed parrot.
 Golden, Helen, Sarasota, Fla., Indian rock python.*
 Goldwyn, Ronald J., Alexandria, Va., 2 Pekin ducks.
 Griffin, D. A., Washington, D. C., barn owl.
 Guy, R. L., Arlington, Va., 2 Pekin ducks.
 Haas, Mrs. F., Washington, D. C., canary.
 Hager, Lester H., Arlington, Va., Florida gallinule.
 Haggerty, Miss Irene, Washington D. C., eastern robin.
 Handley, Charles, Washington, D. C., 2 gray foxes.
 Harriman, D., Washington, D. C., domestic rabbit.
 Harris, Van T., Ann Arbor, Mich., least weasel.
 Harwall, Master Michael, Arlington, Va., barred owl.
 Henderson, Genevieve, Chevy Chase, Md., horned lizard.
 Henshaw, Bill, Washington, D. C., alligator.
 Heslep, C., Silver Spring, Md., eastern robin.
 Hickman, Jean H., Washington, D. C., 4 eastern gray squirrels.
 Hoffman, Dr. Paul, Washington D. C., 2 opossums.
 Hogan, Mrs. Henry, Washington, D. C., eastern robin.
 Holmes, Mrs. G., Washington, D. C., northern raven.
 Householder, Vic. H., Phoenix, Ariz., 4 western green toads, collared peccary.
 Howard, Dr. Walter E., O'Neals, Calif., 4 digger-pine pocket mice, 2 San Joaquin pocket mice, 7 California harvest mice, 16 Gambel white-footed mice, 12 California meadow mice.
 Ingham, Rex, Ruffin, N. C., yellow-naped parrot,* red-blue-and-yellow macaw,* yellow-and-blue macaw,* Mexican green macaw.*
 Ingles, Lloyd G., Fresno State College, Fresno, Calif., mountain beaver, golden-mantle ground squirrel, San Joaquin kangaroo rat, 3 lodgepole-pine chipmunks, California white-footed mouse, San Joaquin antelope ground squirrel, Heerman kangaroo rat, California pocket mouse, Tejon pocket mouse, Merriam's kangaroo rat, 3 small-faced kangaroo rats, southwestern white-footed mouse, 4 pack rats (mother and 3 babies).

- Institut de Recherche Scientifique, Madagascar, 7 leopard chameleons, 2 Du-
meril's boas, 3 lizards.
- Jackson, William, Washington, D. C., barn owl.
- James, Clayton, Landover, Md., purple gallinule, 10 West Indian mourning
doves, * button quail, * spotted salamander.
- James, Cloyd, Purcellville, Va., 2 barn owls.
- Jenkins, R. S., Buenavista, Va., gray fox, skunk, Geoffroy's marmoset.
- Johnson, Duane, W., Washington, D. C., Pekin duck.
- Johnson, F. R., Eustis, Fla., coral snake, eastern diamond-backed rattlesnake.
- Johnson, L., Washington, D. C., rhino beetle.
- Jones, J. M., Silver Spring, Md., 45 white mice.
- Keegan, Capt. Hugh L., Manila, P. I., monitor, reticulated python, 3 river
snakes, 2 akamatahs, 4 Habu vipers.
- King, Charles E., Washington Grove, Md., barn owl.
- Komsa, John, Washington, D. C., raccoon.
- Koon, E. S., Asheville, N. C., alligator.
- Krouse, Mrs. A. F., Washington, D. C., eastern robin.
- Kuntz, Lt. R. E., Cairo, Egypt, 4 Roger's whipsnakes, 7 sand vipers, 11 Egyp-
tian colubers, 4 dassas, javeline boa, 2 desert warals, Egyptian leaf-nosed snake,
"Fish of the Sand," 3 dabbs (or dhabs), mucronate sand lizard, 3 "Father of
Eyes" (cat-eyed snakes), 3 horned vipers, 3 gharibas, 4 aekams, 5 Egyptian
cobras, 3 pale agamas, chameleon, gecko or white "bors," 4 Egyptian
spiny mice, 6 pyramid gerbills, 7 Egyptian sand lizards, Egyptian snails, 16
Egyptian skinks, "Father of Stripes."
- LaGarde, B. L., Frederick, Md., 2 garter snakes, copperhead snake.
- Lane, Dick and Elaine, Washington, D. C., domestic rabbit.
- Lee, Emmett L., Alexandria, Va., 2 barred owls.
- Leonard, Diane Ruth, Washington, D. C., hog-nosed snake.
- Linkins, Mrs. C. S., Washington, D. C., Pekin duck.
- Lionheart, Mrs. Louis, Washington, D. C., eastern gray squirrel.
- Lipscomb, Mrs. Thomas, Washington, D. C., Pekin duck.
- Lohren, Harold, black muskrat.
- Low, S. H., Gaithersburg, Md., alligator.
- Lucas, C. S., East Riverdale, Md., Pekin duck.
- Lyons, James N., Washington, D. C., Pekin duck.
- MacCracken, E., Washington, D. C., red fox.
- Mann, Dr. Guillermo, Santiago, Chile, 3 abrocomas, 3 Gay's frogs, 53 Bibron's
"toad" frogs.
- Marshall, Master Fred, Washington, D. C., snapping turtle.
- Marshall, L. M., Washington, D. C., woodchuck or ground hog.
- McBride, Gordon W., Chevy Chase, Md., domestic rabbit.*
- McDermott, Mrs. Jack C., Washington, D. C., yellow-headed parrot.*
- McDonald, Master Earling, Takoma Park, Md., raccoon.
- Meems Bros. & Ward, Oceanside, L. I., cheetah.*
- Meininger, J. L., Chevy Chase, Md., Pekin duck.
- Meininger, Paul, Bethesda, Md., 2 Pekin ducks.
- Miller, Capt. John, Lima, Peru, 2 Pygmy marmosets.
- Mills, John, Washington, D. C., 10 common newts.
- Mills, L. W., Chevy Chase, Md., opossum.
- Moats, Mr. and Mrs. Edwin R., Hillside, Md., 4 pileated woodpeckers.
- Moebis, Noel, Chevy Chase, Md., barred owl.
- Monahan, Edward P., Trinidad, B. W. I., boa constrictor.
- Moulton, Gladys, Washington, D. C., Cumberland terrapin.*

National Capitol Park Service, Washington, D. C., copperhead snake, pilot snake.
 Naval Research Medical Center, Bethesda, Md., Javan macaque,* 16 East
 African elephant shrews.*

Nicoson, Keith S., Arlington, Va., skunk.

O'Donnell's Grill, Washington, D. C., alligator.

O'Neill, C. A., Washington, D. C., cockatiel.

O'Neill, Chas. F., Washington, D. C., 2 Pekin ducks.

Ord, Edward, Washington, D. C., 2 angel fish.

Ormsby, A. I., Sydney, Australia, 6 black snakes, 6 black-bellied snakes.

Parker, McRea, Leesburg, Va., pilot snake.

Parko, Kendrick, Arlington, Va., timber rattlesnake.

Parsons, Master Tom, Washington, D. C., snapping turtle.

Paugh, Mrs. B., Bristol, Va., opossum.

Peterson, E. G., Arlington, Va., American common crow.

Philadelphia Zoological Society, Philadelphia, Pa., ocellated turkey,* mallard
 duck (gift).

Phillips, Chester, and McComb, Robert, Washington, D. C., barred owl.

Preston, J. E., Washington, D. C., lesser white-nosed guenon.*

Putnam, Pat, Belgian Congo, chameleons and francolins.

Randel, Capt. Hugh W., Canal Zone, 3 Galápagos iguanas, Galápagos tortoise.

Reed, R. W., Washington, D. C., cardinal.

Reegan, T. V., Washington, D. C., eastern gray squirrel.*

Rivere, Dr. Luis Howell, Havana, Cuba, hutia.

Robey, J. C., Washington, D. C., golden hamster.

Robinson, George A., McPherson, Kans., coyote.

Rosenberg, Louis, Washington, D. C., Virginia rail.

Rottmund, F. G., Silver Spring, Md., pied-billed grebe.

Rusch, James L., Washington, D. C., rhesus monkey.*

Ryder, Mrs. Stephen, Silver Spring, Md., 3 Pekin ducks.

San Diego Zoological Society, San Diego, Calif., spectacled bear.

Santos, Mrs. J., Washington, D. C., skunk.

Schneider, Mrs. T. F., Dragoon, Ariz., gila monster.

Sharpe, C. J., Takoma Park, Md., Pekin duck.

Shaw, Harry L., Baltimore, Md., Hamadryas baboon.*

Sherwood, Harry, Washington, D. C., domestic rabbit.

Sloan, J. L., Salt Lake City, Utah, 2 ring-billed gulls, 2 badgers.

Smith, Master Dorsey, Clifton, Va., skunk.

Snyder, E. T., Washington, D. C., Pekin duck.

Snyder, Dr. T. E., Beltsville, Md., snapping turtle.

Souder, Harry N., Washington, D. C., brown capuchin.

Spliden, Ronald, Landover, Md., pied-billed grebe.

Springer, Paul, Laurel, Md., gray-cheeked thrush.

Stanley, Misses Jeanne and Mary Ann, Washington, D. C., 2 Pekin ducks.

Steelman, S/Sgt. Carl T., Bolling Field, D. C., woodchuck or ground hog.

Steger, Mrs. Mary E., Falls Church, Va., 2 grass parakeets.

Stevenson, Mrs. Elva Myers, Washington, D. C., rhesus monkey.*

Stinnett, Bob, Cameron, Mont., cinnamon bear.

Stogdhill, Howard, Washington, D. C., Pekin duck.

Stomn, Mrs., Arlington, Va., American crow.*

Strates, J. E., Shows, Inc., Alexandria, Va., lion.
 Sturgell, David A., Berwyn, Md., skunk.
 Sunday, Richard, Arlington, Va., eastern chipmunk.
 Surles, George L., Washington, D. C., Philippine macaque.
 Swope, Miss Alice C., Washington, D. C., Pekin duck.
 Tolman, Ruel P., Washington, D. C., flying squirrel.
 Townsend, Mrs. Thomas, Washington, D. C., 2 domestic rabbits.
 Traub, Maj. Robert, Army Medical Center, Malaya, 2 bamboo rats, 2 slow loris, Malayan cat, 2 *Callosciurus nigroviridis*, 2 gray tree rats, 2 large spiny-backed tree rats, 2 Edward's tree rats, 2 Muller's tree rats, 2 rajah tree rats, 2 pencil-tailed tree rats, Bower's tree rat, Whitehead's tree rat.
 Treffich's Bird and Animal Co., Inc., New York, N. Y., 3 great gray kangaroos.*
 U. S. Fish and Wildlife Service, Patuxent, Md. (through Arnold Nelson), 4 bobwhites, 9 opossums.
 U. S. Fish and Wildlife Service, Washington, D. C. (through Leon Cool, Jr.), 2 whistling swans, whistling swan.*
 U. S. Fish and Wildlife Service, Willows, Calif. (through Vernon Ekedahl), 10 cackling geese.
 U. S. Naval Hospital, Bethesda, Md., Poland-China hog.
 U. S. Public Health Service, Bethesda, Md. (through Dr. H. W. Stunkard), golden baboon.
 Vevers, Mr. and Mrs. G., London, England, 2 dormice.
 Wagner, Mrs. Henry S., Front Royal, Va., 22 canaries.
 West, Master David, and Manfuso, Master Bob, Chevy Chase, Md., opossum.
 White, Miss Becky, Washington, D. C., opossum.
 White, Miss Inez, Washington, D. C., Muscovy duck.
 Whitehead, Mrs. Virginia, Washington, D. C., 2 Pekin ducks.
 Widham, Mrs. Spencer, Silver Spring, Md., ring-necked pheasant.
 Williamson, A. A., Washington, D. C., 6 white cloud mountain fish, 6 zebra fish, 6 head-and-tail-light fish, rio tetra, 2 black tetra, South American catfish.
 Williamson, F. S. L., San Diego, Calif., California king snake, 2 glossy snakes, 5 red rattlers, 2 rosy boas, 3 gopher snakes, 2 alligator lizards, Pacific rattler, striped racer.
 Wilson, Mrs. Arnold, Washington, D. C., 2 grass parakeets.
 Wools, Wm. P., Alexandria, Va., Pekin duck.
 Wright, Jack, and Davis, Harvey, Arlington, Va., red-bellied terrapin.
 Young, C. N., Silver Spring, Md., raccoon.
 Zicse, A., Washington, D. C., domestic rabbit.
 Zoological Society of London, London, England, 4 Chinese water deer, 1 kusi-manse, 2 dormice, 6 jackdaws, 2 European jays, 2 purple touracous, 1 plover, and 2 Meller's chameleons.

BIRTHS AND HATCHINGS

MAMMALS		
Scientific name	Common name	Number
<i>Ammotragus lervia</i>	Aoudad.....	4
<i>Aotus trivirgatus</i>	Owl or night monkey.....	1
<i>Ateles geoffroyi vellerosus</i>	Spider monkey.....	1
<i>Axis axis</i>	Axis deer.....	2
<i>Bibos gaurus</i>	Gaur.....	1
<i>Bos taurus</i>	English Park cattle.....	1
<i>Bos taurus</i>	West Highland cattle.....	1

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
<i>Bubalus bubalis</i>	Water buffalo.....	1
<i>Camelus bactrianus</i>	Bactrian camel.....	1
<i>Capromys pilorides</i>	Hutia.....	3
<i>Cephalophus nigrifrons</i>	Black-fronted duiker.....	1
<i>Cercopithecus aethiops sabaesus</i>	Green guenon.....	1
<i>Cercopithecus aethiops sabaesus</i> × <i>C. a.</i> <i>pygerythrus</i>	Hybrid green guenon × ver- vet guenon.....	1
<i>Chinchilla chinchilla</i>	Chinchilla.....	4
<i>Choeropsis liberiensis</i>	Pigmy hippopotamus.....	1
<i>Cyclopes didactylus</i>	Pigmy or silky anteater.....	1
<i>Dama dama</i>	Brown fallow deer.....	2
<i>Dama dama</i>	White fallow deer.....	5
<i>Felis concolor</i> × <i>F. c. patagonica</i>	Hybrid North American × South American puma.....	2
<i>Felis tigris</i>	Tiger (Bengal).....	5
<i>Giraffa camelopardalis</i>	Nubian giraffe.....	1
<i>Hippopotamus amphibius</i>	Hippopotamus.....	1
<i>Hydropotes inermis</i>	Chinese water deer.....	2
<i>Lama glama guanico</i>	Guanaco.....	1
<i>Lama pacos</i>	Alpaca.....	1
<i>Lemur macacao</i>	Acoumba lemur.....	1
<i>Odocoileus virginianus</i>	Virginia deer.....	1
<i>Oncifelis geoffroyi</i>	Geoffroy's cat.....	1
<i>Ovis europaea</i>	Mouflon.....	1
<i>Phloeomys cumingi</i>	Slender-tailed cloud rat.....	2
<i>Rattus canus</i>	Tree rat.....	3
<i>Syncerus caffer</i>	African buffalo.....	1
<i>Thalarcos maritimus</i> × <i>Ursus middendorffi</i>	Hybrid bear.....	2

BIRDS

<i>Agriocharis ocellata</i>	Ocellated turkey.....	5
<i>Anas platyrhynchos</i>	Mallard duck.....	12
<i>Branta canadensis</i>	Canada goose.....	12
<i>Cairina moschata</i>	Muscovy duck.....	5
<i>Fulica americana</i>	American coot.....	10
<i>Gallus gallus</i>	Red jungle fowl.....	1
<i>Gennaeus leucomelanus</i>	Nepal pheasant.....	6
<i>Larus novaehollandiae</i>	Silver gull.....	4
<i>Pavo cristatus</i>	Peafowl.....	1
<i>Taeniopygia castanotis</i>	Zebra finch.....	6

REPTILES

<i>Crotalus adamanteus</i>	Eastern diamond-backed rat- tlesnake.....	5
<i>Epicrates cenchris</i>	Rainbow boa.....	18
<i>Natrix</i> , sp.....	Water snakes.....	8
<i>Tiliqua nigrolutea</i>	Black-barred skink.....	5
<i>Tiliqua scincoides</i>	Blue-tongued skink.....	3

FEEDING THE ANIMALS

To feed such a collection of animals with their varied requirements presents a considerable problem. At the beginning of the war, prices for many of the green types of food had gone so high that the use of such material was almost prohibitive, although it is essential for the well-being of many of the animals. Therefore the Zoo inaugurated a system of obtaining from nearby grocery stores the outer leaves of lettuce, cabbage, cauliflower, and other material that would normally go into the refuse. This material is picked up daily and is sorted to make certain that it is in suitable condition. The animals have thrived, the cost for such green food has been held to a minimum, and it was thus possible to keep out of competition for human food when such material was scarce. The arrangement has been so satisfactory that it is being continued.

During the war the United States Marshal's office made arrangements to turn over to the Zoo food that had been condemned in the courts as unsuitable for human consumption. That office has continued to send considerable quantities and many different kinds of such food. The Zoo also frequently receives offers from private individuals or business houses of food that they wish to dispose of without having to go through the court procedure of condemnation. Thus diversified food was received for the animals, which greatly aided in keeping down the cost of feeding.

MAINTENANCE AND IMPROVEMENTS

In the lion house many of the old cages were extensively repaired, and a portion of the steam conduit under the building was repaired and improved. Concrete floors were laid in the outside cages at the monkey house, and 6-inch concrete slabs were laid between the sidewalk and the cages around the stone cat houses. A sidewalk was built from the small-mammal house to the walk between the reptile house and the antelope building.

By clearing and surfacing additional land, the capacity of the bus-parking area was increased from 20 to 40 busses. The capacity of the automobile-parking area also was increased from 650 to 750 automobiles.

For the third successive year the fight by chemical means against poison ivy continued, and very little of this plant pest remains in areas commonly frequented by the public. Increased efforts have been directed toward improving the appearance of the grounds, caring for the lawns, planting trees and shrubs, and carrying on other gardening work. As a whole, satisfactory progress has been made in returning to normal maintenance.

VISITORS

The total attendance was 3,346,050, an increase of 305,510 over the previous year. This was the largest attendance in the history of the Zoo and is probably due in part to the continued high employment in the Washington area, increase in travel accompanying the general economic prosperity, and the frequency with which we were able to announce the addition of interesting specimens to the collection. The variation in attendance on the different days of the week which was so extreme before the war has been much less noticeable since the war. Formerly early days of the week had relatively low attendance, with an increasing number of visitors the latter portion of the week and with very large crowds on Saturdays, Sundays, and holidays. There is also a considerable increase in attendance in the earlier hours of the day.

ESTIMATED NUMBER OF VISITORS FOR FISCAL YEAR 1949

July (1948).....	424, 000	February.....	167, 700
August.....	468, 000	March.....	245, 300
September.....	339, 000	April.....	375, 500
October.....	230, 300	May.....	410, 500
November.....	169, 400	June.....	299, 900
December.....	49, 450		
January (1949).....	167, 000	Total.....	3, 346, 050

Groups came to the Zoo from schools in 25 States, some as far away as Maine, Florida, Texas, and California. One group of 33 persons came from Havana, Cuba.

NUMBER OF GROUPS FROM SCHOOLS

	Number of groups	Number in groups		Number of groups	Number in groups
Alabama.....	7	197	Mississippi.....	2	35
California.....	1	158	New Jersey.....	23	1, 374
Connecticut.....	8	497	New York.....	95	5, 682
Delaware.....	7	385	North Carolina.....	184	5, 320
District of Columbia	132	7, 822	Ohio.....	47	1, 647
Florida.....	6	672	Pennsylvania.....	245	12, 261
Georgia.....	48	1, 819	South Carolina.....	39	1, 119
Illinois.....	1	21	Tennessee.....	33	1, 453
Indiana.....	12	451	Virginia.....	362	19, 312
Kentucky.....	9	291	West Virginia.....	50	2, 425
Maine.....	12	775			
Maryland.....	525	28, 850	Total (States).....	1, 843	93, 599
Massachusetts.....	7	374	Havana, Cuba.....	1	33
Michigan.....	16	674			
Minnesota.....	2	76	Total.....	1, 844	93, 632

About 2 p. m. each day the cars then parked in the Zoo are counted by the Zoo police and listed according to the State, Territory, or country from which they came. This is, of course, not a census of the cars coming to the Zoo, but is valuable in showing the percentage

of attendance, by States, of people in private automobiles. The tabulation for the fiscal year 1949 is as follows:

	Percent		Percent
Washington, D. C.-----	26.9	Ohio-----	1.7
Maryland-----	26.4	West Virginia-----	1.4
Virginia-----	20.5	New Jersey-----	1.3
Pennsylvania-----	4.4	Massachusetts-----	.9
New York-----	2.5	Florida-----	.9
North Carolina-----	2.0	California-----	.8

The cars that made up the remaining 10.30 percent came from every one of the remaining States, as well as from Alaska, Bahamas, Canada, Canal Zone, Chile, Cuba, Guam, Hawaii, Honduras, Italy, Japan, Mexico, Netherlands, Newfoundland, Poland, Puerto Rico, Sweden, Trieste, Trinidad, and Virgin Islands.

It is well known that District of Columbia, Maryland, and Virginia cars bring to the Zoo many people from other parts of the United States and of the world, but no figures are available on which to base percentages.

FINANCES

The regular appropriation provided in the District of Columbia appropriation act was \$492,600, and there was a supplemental appropriation in the second deficiency bill of \$36,248 to provide for the increased salaries of \$330 per annum authorized by Congress. Of the total of \$528,848 which was available, about \$11,474 will remain unexpended, subject to minor changes in final bills. This saving was mainly from salaries because of the impossibility of filling positions promptly.

The stone restaurant building, which was constructed in the park in 1940 under an allotment of \$90,000, is under a 3-year lease obtained by competitive bidding at \$10,212 per annum. This money is deposited in the general fund of the United States Treasury. The concessionaire serves meals and light refreshments, and sells novelties.

NEEDS OF THE ZOO

The chief need of the Zoo is for the replacement of antiquated structures that have long since ceased to be suitable for the purpose. The more urgently needed buildings are: (1) A new administration building to replace the 144-year-old historic landmark now in use for an office building for the Zoo, but which is neither suitably located nor well adapted for the purpose. This building is in an excellent location for a public recreational structure, and could probably be rehabilitated and used for recreational purposes, perhaps as a children's

museum, and thus maintained as a historic building. The new office building should be better located both from the standpoint of accessibility to the public and convenience for the administration of the Zoo. (2) A new building to house antelopes and other medium-size hoofed animals that require a heated building.

STATUS OF THE COLLECTION

Class	Species	Individuals	Class	Species	Individuals
Mammals.....	235	786	Crustaceans.....	1	2
Birds.....	346	1,911	Arachnids.....	2	3
Reptiles.....	121	509	Insects.....	1	100
Amphibians.....	22	164	Mollusks.....	3	23
Fish.....	24	226	Total.....	755	3,724

SUMMARY

Animals on hand July 1, 1948..... 2,797
 Accessions during the year..... 1,751

Total number of animals in collection during the year..... 4,548
 Removals for various reasons such as death, exchanges, return of animals
 on deposit, etc..... 824

In collection on June 30, 1949..... 3,724

Respectfully submitted.

W. M. MANN, *Director.*

Dr. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 8

REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: I have the honor to submit the following report on the operations of the Astrophysical Observatory for the fiscal year ended June 30, 1949:

The Observatory includes two research divisions: (1) the Division of Astrophysical Research, concerned chiefly with solar radiation problems, and (2) the Division of Radiation and Organisms, concerned with the biological effects of radiation.

During the year a new room adjoining the Director's office was built for the administrative assistant and for the files of the Observatory. The resulting consolidation of needed information near at hand has materially improved the efficiency of operation.

Considerable progress can be reported concerning the new revised editions of the Smithsonian Meteorological Tables and the Smithsonian Physical Tables, mentioned in last year's report. R. J. List, editor of the Meteorological Tables revision, had practically completed his manuscript at the end of the fiscal year. The difficult task of revising the Physical Tables, the last revision of which had been issued in 1934, was begun in September 1948 under the direction of Dr. W. E. Forsythe. An office in Cleveland, Ohio, and an assistant were furnished to Dr. Forsythe. At the close of the fiscal year he reports that approximately one-half of the tables for the new edition have been completed.

(1) DIVISION OF ASTROPHYSICAL RESEARCH

Previous to 1946 the Observatory had for many years maintained three high-altitude field stations for solar-constant observations. In 1946 the Tyrone station, which for 7 years had been operated on Burro Mountain (altitude 8,000 ft.) in southwestern New Mexico, was abandoned because skies there had progressively deteriorated, mainly the result of increasing mining and smelting operations in that general region. As a temporary measure, to aid in certain studies referred to below under contract with the Quartermaster Corps, the Tyrone station equipment was transferred to and installed at Miami, Fla. Since then much effort has been spent to find the most suitable location for a third high-altitude field station to replace the abandoned Tyrone site. In last year's report we mentioned that after

careful investigation three promising sites had been chosen for further study and that in May 1948 a recording Eppley pyrhelimeter was installed at each of these sites, namely, (1) Torreón, Coahuila, México; (2) Mountain Pass, near Clark Mountain, California; and (3) Pohakuola, Hawaii. The three pyrhelimeters were operated for a period of 1 year, ending June 1949. The resulting records indicate the uniformity and the quality of the sky for each day during the period. It is clear from the records that the best skies prevailed at the Clark Mountain location. The second-best site was Pohakuola. This spot, 6,500 feet above sea level on the Island of Hawaii, yielded some records of unusually clear and uniform skies, but such skies were not the rule. At Clark Mountain, during the period June 8 to March 31, there were 171 days with skies sufficiently good for satisfactory observations, while at Table Mountain, Calif., during the same period actual observations were made on 135 days. From studies of these records and other sources, it appears that the Clark Mountain region is in general considerably drier and more free of haze and clouds than any other high-altitude location at present known in the northern hemisphere.

In view of this, estimates were obtained of the cost of establishing a field station at an altitude of 6,500 feet on the south slope of Clark Mountain. Owing to the prevailing high prices for building materials and labor, the estimates proved to be in excess of available funds. It is hoped that sufficient funds may become available, but pending this the Observatory plans immediately to enlarge its facilities at Table Mountain sufficiently so that it will be possible to proceed without delay with the special experimental problems mentioned in last year's report.

Work at Washington.—W. H. Hoover, Chief of the Division, in addition to supervision of the work in progress, prepared data and tables which will help to simplify the computations in the field. In the past, to obtain the air mass (or length of path of the solar beam in the atmosphere) it has been necessary to plot carefully a series of theodolite readings against time, to read off desired altitude values, and finally to enter an air-mass-altitude table. With the aid of Hoover's data, the observer, by reading the theodolite at specified intervals, may enter the tables directly to determine the air mass. This eliminates the tedious curve-plotting process.

A new instrument, designed by Dr. John W. Evans, of the High Altitude Observatory of Harvard University, and described by him in the *Journal of the Optical Society of America*, December 1948, was kindly lent to the Astrophysical Observatory by Dr. Menzel of Harvard University to test and to determine its adaptability to Smithsonian work. The instrument is a photometer especially designed

for determining the brightness of the sky immediately surrounding the sun. Excellent results have been obtained with it at the Harvard Station at Climax, Colo. It is of considerable interest to compare its readings with simultaneous readings of the Smithsonian pyranometer which also measures the brightness of the sky in a zone around the sun. In preparation for comparison tests a rigid mounting has been prepared for the instrument with slow-motion adjustment in altitude and azimuth.

During the fiscal year, two silver-disk pyrheliometers, Nos. 80 and 81, were built, calibrated and sold at cost, one to the Hebrew Institute of Technology, Haifa, Palestine, and the other to the Dublin Institute for Advanced Learning. In addition two modified Angstrom pyrheliometers and one special instrument for the spectroscopic determination of atmospheric water vapor have been prepared for the Belgium Meteorological Institute. These were nearly completed at the end of the year.

Dr. C. G. Abbot, research associate of the Observatory, continued his studies of the dependence of weather upon solar changes. This work has been published in Smithsonian Miscellaneous Collections, vol. 111, Nos. 5, 6, and 7. Dr. Arctowski's studies of solar and terrestrial atmospheres were retarded by illness, but his work was resumed before the close of the year.

Work in the field.—Daily observations of the solar constant were in progress throughout the year, as far as skies permitted, both at Montezuma, Chile, and at Table Mountain, Calif. The skies during the year were apparently normal at Table Mountain, but at Montezuma the observers noted an unusual number of days with light cirrus clouds.

Early in the year Mr. Hoover carried the Observatory's substandard silver-disk pyrheliometer S. I. No. 5 to Miami for direct comparisons with the pyrheliometers at that station. In February 1949, in the course of changing the personnel at Montezuma, Chile, substandard S. I. No. 5 was carried to Montezuma by the new Montezuma observer, and brought back in April by the retiring observer, after inter-comparisons had been made in Chile. The previous year S. I. No. 5 had been carried to Table Mountain by the director for similar inter-comparisons. Thus there are now very recent direct comparisons between all field pyrheliometers and substandard S. I. No. 5, which in turn was carefully compared in 1947 with the absolute water-flow standard. These many inter-comparisons show no material changes in constants. They satisfactorily confirm the adopted scale of pyrheliometry. A revision of Dr. Abbot's paper of 1922 on "The Silver-disk Pyrheliometer" is in preparation, summarizing the constants of all silver-disk pyrheliometers, and describing certain changes which

have been adopted in recent years, both in the instrument itself and in the method of use.

In June 1945 special radiation measurements were started at Camp Lee, Va., under contract with the Office of the Quartermaster General, in connection with their long-range study of the causes for the deterioration of tents and tent materials. This contract has been renewed each year since then, and the work has now extended to include similar radiation measurements at Miami, Fla., a wet, sea-level station, and at Montezuma, Chile, a dry, high-altitude station. The Observatory completed the Camp Lee measurements January 1, 1948, and since then they have been continued by the Quartermaster Board at Camp Lee, with the Observatory acting in an advisory capacity, and giving assistance when difficulties arise. The measurements at Miami, begun in December 1947, have continued throughout the present fiscal year. Similar radiation measurements and textile exposures were begun at Montezuma, Chile, in December 1948, and will continue approximately 2 years. Five reports to the Office of the Quartermaster General were made during the year summarizing the data obtained at Miami and at Montezuma.

In January 1949, the Director visited the Miami field station, to inspect the work in progress. While there he obtained special bolographs showing the absorption effects of known quantities of water vapor in the atmosphere. Measurements of these bolographs confirmed the correctness of precipitable water curves which Mr. Fowle had determined in earlier work at Washington and which have since been used many times in our solar-constant program. This work is discussed in Smithsonian Miscellaneous Collections, vol. 111, No. 12, soon to be issued.

(2) DIVISION OF RADIATION AND ORGANISMS

(Report prepared by Dr. R. B. Withrow)

The work of the Division for the past year has been concerned chiefly with reorganizing and reequipping the laboratories. New office space has been established in conjunction with the basement laboratories. These offices have been furnished with desks and cases and will accommodate a maximum of nine individuals.

Most of the laboratories have been repainted and are being reequipped with modern lighting facilities. The laboratory furniture has been reconditioned and new metal furniture ordered to supplement that already available.

Five rooms are being converted into constant-condition rooms for biological experimentation with equipment for controlling the temperature, humidity, radiation, and nutritional environment.

Four chemistry laboratories will be available, including a general laboratory, a balance room, a dark room held at room temperature for pigment analyses, and an insulated and air-conditioned dark room controlled at 0° C. or above for protein and enzyme analyses.

In addition, a photographic laboratory, a room for X-ray facilities, a cytology laboratory, an electronics laboratory, and two general laboratories are being set up, all of which are being designed with new plumbing to supply gas, compressed air, and water, and with new electrical power outlets.

The Research Corporation has very generously made a grant to the Division for reequipping the laboratories with modern experimental facilities and for work on the mechanism of visible radiation on growth processes in plants. The Division also has been assigned a contract by the Chemical Corps, Department of the Army, providing funds for personnel and equipment for research on the effect of growth regulators on metabolic activities of plant tissues.

Respectfully submitted.

L. B. ALDRICH, *Director.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 9

REPORT ON THE NATIONAL AIR MUSEUM

SIR: I have the honor to submit the following report on the operations of the National Air Museum for the fiscal year ended June 30, 1949.

INTRODUCTION

This year, the first full year of the National Air Museum as a bureau of the Smithsonian Institution, was one of many activities. In addition to normal museum operations, the bureau was concerned especially with the return from England of the Wright Brothers' renowned aeroplane, the *Kitty Hawk*; with the acquisition and management of a field storage facility; with the accession of the U. S. Air Force aircraft collection; and with the basic study and planning for a site and building for the aeronautical collections.

Early in 1948 the Institution was informed that the late Dr. Orville Wright had expressed the desire to present the *Kitty Hawk* to the United States National Museum and that the executors of Dr. Wright's estate would institute the necessary legal action to bring this about. Prior to the receipt of this news the Smithsonian had effected the administrative transfer of all aeronautical museum activities and experienced personnel from the National Museum to the newly established National Air Museum. Therefore, in order to have the expert assistance of the Air Museum staff, the Secretary, through the Director of the National Museum, delegated to the National Air Museum the responsibility for the reception, exhibition, and preservation of the Wright plane. The details are indicated under Curatorial Activities presented later in this report.

Negotiations begun last year with the U. S. Air Force to acquire a storage depot for the Air Museum were successfully consummated on November 1, 1948. On that date the bureau was granted occupancy of 267,475 square feet of floor space within building T-6 of the former Douglas Aircraft plant at Chicago Orchard Airport, Park Ridge, Ill., and installed a field organization to operate the facility. On the same date the Museum assumed tentative custody (pending inventory) of the large aircraft collection stored in this building by the Air Force and on May 1, 1949, upon completion of the inventory, assumed full responsibility for its preservation.

Along with these several extra activities the bureau continued, with the Office of Design and Construction of the Public Buildings Administration, the further study of sites and a building for the Museum. This was done in accordance with the recommendation of the Advisory Board. The result of the study is recorded later in this report.

No changes were made during the year in the departmental organization of the bureau except the occasional employment of temporary clerical help. This was especially necessary in connection with the reception and exhibition of the Wright Brothers' aeroplane. The bureau found it difficult, on the other hand, to fill several positions available at its field storage facility because of the higher wage scale prevailing in the Chicago area for comparable work. As a result, the work program planned for this field organization was not fully carried out. In all other respects the bureau completed the year in good condition.

ADVISORY BOARD

In April of this year the Board experienced a change in membership as a result of the retirement of its U. S. Air Force representative, Maj. Gen. E. M. Powers. General Powers had served on the Board since its inception late in 1946, having been designated to the office by General Spaatz. His wise counsel during the formative days of the establishment of the National Air Museum was most helpful. To succeed him on the Board, Gen. H. H. Vandenberg, Chief of Staff, Department of the Air Force, designated Maj. Gen. Grandison Gardner who met with the Board for the first time at its sixth meeting in June 1949.

During the year three meetings of the Advisory Board were held in Washington, on August 26, 1948, December 20, 1948, and June 29, 1949. Deliberations in these meetings were directed principally toward the advancement of the Air Museum's major projects, namely, the acquisition of a building site and a suitable museum building in the Washington area.

As directed by the Board at its August 1948 meeting, the study of a suitable museum building was continued this year in cooperation with the Public Buildings Administration.

STORAGE OF MUSEUM MATERIAL

In accordance with a resolution adopted by the Advisory Board last year, the bureau completed negotiations on November 1, 1948, to take over the storage operations of that portion of one of the former Douglas Aircraft buildings (T-6) at the Chicago Orchard Airport, Park Ridge, Ill., containing the collection of aeronautical museum material stored there by the United States Air Force for the National

Air Museum. Some additional floor space within this building, adjacent to that containing the Air Force collection, together with two two-floor structures erected therein and suitable for office use, was acquired at the same time.

Immediately following this transaction the bureau installed a field organization to operate the facility, consisting of an associate curator in charge, an aircraft technician, and a guard force to patrol the area 24 hours a day. Until February 1, 1949, the military personnel of the Air Materiel Command of the U. S. Air Force, which had been detailed to care for the Air Force collection, remained on duty to assist the bureau's organization in readying itself to assume its responsibilities. With this accomplished, three programs of work were initiated: (1) The rearrangement by classes of the aeronautical materials packed in boxes and crates; (2) the cleaning and sealing of all openings of assembled aircraft and rust-proofing of component parts; and (3) the inspection and inventory of all items composing the collection preparatory to its transfer from the Air Force to the Air Museum.

On May 1, 1949, the inventory was completed and the transfer was effected of 1,366 aeronautical objects including 97 aircraft to the Air Museum. The preservation work was in progress at the end of the year.

While these activities were in progress the bureau took steps to provide the maximum protection of the materials in storage. In addition to the acquisition of hand fire extinguishers installed in fixed positions over the area and of larger extinguishers mounted on hand trucks, an intercommunicating system was selected and a contract let for its installation at 12 stations distributed strategically over the Museum's storage area. This will enable a guard on patrol to communicate quickly with the administration office in any emergency. The bureau also designed and contracted for the construction and erection of a high wire fence to enclose the major part of the area. These projects were in progress at the end of the year.

PLANNING

MUSEUM SITE AND BUILDING

During the year the bureau continued the investigation of sites and a building for the Air Museum. For this purpose it had the valuable cooperation of the Federal Works Agency, Public Buildings Administration, Office of Design and Construction, through an arrangement involving the transfer of funds.

Planning and designing a museum building for aircraft and aviation collections involves factors not usually encountered in museum structures. For example, although the history of practical aviation spans a comparatively short period of years, the steps in its development

are many. Therefore, there must be imposed limitations of selection of materials of both historical and technological significance not only to avoid incomprehensive public displays but also impractical housing requirements. The aeronautical collections will include material both of small and uncommonly great dimensions and weight. Experience indicates that approximately 30 percent of the total available floor area of a technical museum structure is required for its maintenance and operations services and that for the safety of the visiting public ample passageways must be established in all exhibition areas. It can be readily understood that these requirements necessitate a compromise between the ideal and a realistic aviation museum building.

Both the Advisory Board and the bureau's staff gave careful attention during the year to factors such as these which brought about a number of changes in the plans originally developed last year.

CURATORIAL ACTIVITIES

The curator, Paul E. Garber, reports on the year's work as follows:

At the beginning of the fiscal year the staff was moved into new and improved quarters which provided more facilities for the expanding personnel. Office and shop equipment were acquired, an efficient procedure for handling correspondence was adopted, and added space was allocated to the library, the reference files, and the photographic files. The constant efforts of the staff in the maintenance of the exhibits are reflected in the improvement of individual displays, but the extreme overcrowding in the present Aircraft Building and the Aeronautical Hall assigned to the bureau in the Arts and Industries Building has approached the danger point to both visitors and specimens. As a result, the addition of large exhibits has been brought to a standstill. Happily, the facility at Park Ridge, Ill., provides for the storage of material which might otherwise be lost to the Museum. Only by the acquisition of a permanent building for the Museum in the Washington area can this situation be corrected.

EXHIBITION

The outstanding accomplishment of the year was the receipt of the Wright Brothers' aeroplane of 1903 and its exhibition and preparation for the presentation ceremony on December 17, 1948, the forty-fifth anniversary of its historic flight. The curator was assigned the pleasant duty of representing the Smithsonian in meeting Dr. Herman Shaw, Director of the Science Museum, London, and of accepting from him at Halifax, Nova Scotia, custody of the aeroplane. This was effected on November 12, and following the transfer of the aeroplane from the S. S. *Mauretania* to the Navy Carrier U. S. S. *Palau*, the curator accompanied the plane to Bayonne, N. J., saw to its re-loading on a Navy truck and accompanied the truck convoy to the

National Museum. There the *Spirit of St. Louis* had been moved so that the two noted aircraft could share the same North Hall of the Arts and Industries Building and, with the assistance of photographs and drawings provided by M. J. B. Davy of the Science Museum, the *Kitty Hawk* was assembled. Some details of the engine and transmission were installed from sketches and photographs furnished by Charles Taylor, the mechanic who assisted the Wrights in the original construction of the plane and engine. The aeroplane was suspended in the front of the hall with cables and splices donated by the Jacoel Equipment Co. At the ceremony of presentation, the "Early Birds," the association of pioneer pilots, many of whom had been trained by the Wrights, were among the honored guests. A number of them have since augmented the *Kitty Hawk* exhibit by donations of their own records and relics. Acknowledgments are also made to the Air Force Technical Museum and to S. Dunham, Dayton, Ohio, for photographs and drawings for addition to the Museum's reference and exhibition material on the Wrights. At the close of the fiscal year progress is being made on an auxiliary exhibition case to be placed under the *Kitty Hawk* in which the story of the Wright Brothers will be told in detail.

As the National Air Museum progresses, its purposes and services have become better known, and very helpful cooperation has been received in the matter of accessions. The following examples are outstanding. The presentation of Alford Williams' renowned *Gulfhawk-2* October 11, followed an impressive flight-demonstration of the remarkable aerobatic combination of pilot and plane. The Gulf Oil Company formally presented the airplane at the National Airport and soon after, Major Williams' technician, Frank Tye, who had maintained the plane in splendid condition throughout its 12 years of strenuous flying, assembled it in the Aeronautical Hall. The Department of the Navy, Bureau of Aeronautics, repaired and transferred a Japanese Baka Bomb to the Museum and provided, as auxiliary material, examples of both jet and rocket engines used in these "suicide planes." The collection of scale models which reviews the evolution of aircraft used in Naval service was improved by 10 recent types received from manufacturers who produced the original planes for the Navy. The Department of the Navy assisted also in the special anniversary celebration held in the Aircraft Building to commemorate the thirtieth anniversary of the first trans-Atlantic aircraft flight made by the *NC-4*. An illustrated description of this Curtiss-built flying boat, the hull of which is in the Museum, was prepared by the staff and printed by courtesy of the Curtiss-Wright Corporation. Speakers included Vice Adm. John D. Price, U. S. N., and Capt. Holden C. Richardson, U. S. N., Ret.

The first Roadable Autogyro, transferred from the Civil Aeronautics Administration, was reconditioned by them for museum purposes. In the previous report, the services of the Air Force were acknowledged in moving the Army Curtiss Racer from the Aircraft Building to the Aeronautical Hall—a move made necessary by restricted space. This year, the plane was equipped with the original floats with which Lt. (now General) James Doolittle won the Schneider Trophy Race in 1925. The bracing wires for this restoration were kindly provided by the MacWhyte Company, Kenosha, Wis. Valuable assistance was received this year from the Air Force in unloading and mounting four large engines donated by the Wright Aeronautical Corporation, in covering with Plexiglas the sides of the DeHavilland-4 and Gen. William Mitchell's Spad-16, and in replacing the windows in the first nonstop transcontinental airplane, the *T-2*.

The exhibit which illustrates the accomplishments of John Joseph Montgomery of California, a renowned pioneer of gliding whose first glides were made in 1883, received additions through the cooperation of the Montgomery family, the San Diego Junior Chamber of Commerce, and the biographer, Winsor Josselyn. Through the generosity of the Firestone Tire and Rubber Company, the wheels on the Voisin bomber of World War I were equipped with tires. In the auxiliary exhibit which accompanies the Flagplane of the First World Flight, the group of portrait sculptures were renovated by its sculptor, Joseph A. Atchison, and the stereopticon story of this flight was reactivated. A special exhibition of model aircraft as flown by hobby enthusiasts was prepared in August 1948 during the period of the national show and contest. Improvements were made in the display of Col. Charles Lindbergh's accessories and flight clothing. Extensive cleaning, rearranging, labeling, and repairing have brought the exhibits to a condition believed to be as presentable as the crowded conditions and work program permit.

Special exhibitions arranged by the staff and involving the use of Museum material away from the bureau included a group of cases set up by Bolling Field for the Air Force anniversary on September 18, containing engines, models, and relics of the military air arm; and the loan of the original Liberty engine and models of historic Air Force planes for the technical exhibit and air show held at Andrews Field, Maryland, February 15.

STORAGE

Among the numerous aircraft installed this year in the Museum's storage facility at Park Ridge, Ill., was the *Swoose*, flown there under its own power. This historic B-17-D bomber had served throughout World War II from Bataan to the defeat of Japan. Completing its military career as the command plane of Gen. George H. Brett, the

Swoose was acquired by the city of Los Angeles as a war memorial. In 1948 the city, through Mayor Fletcher Bowron, presented the plane to the National Air Museum, and with the cooperation of Grover Loening and Maj. Gen. E. M. Powers of the Advisory Board, arrangements were made for the reconditioning of the plane by the Air Force. In due time this was accomplished under the direction of the *Swoose's* wartime flight engineer, Captain Boone, and in April 1949, with its wartime pilot, Col. Frank Kurtz, at the controls, the plane was flown to the Chicago Orchard Airport and delivered there to the Museum's storage facility. The Air Force cooperated not only in this spectacular delivery but also in the tremendous project of transferring its huge collection of trophy aircraft and accessories to Museum custody. The screening, cataloging, and arrangement of this stored collection at Park Ridge was under way as the year closed.

The historic and trophy aircraft and engines which are being assembled for the Museum by the Department of the Navy are stored at Norfolk, Va. During the year the curator inspected this facility, checking the condition of the *NC-4's* wings and other parts, the Japanese "Emily," the German Dornier 335 which had recently been moved there, and the service types which are in "canned" containers. All were in good condition.

Acknowledgments are made to Eastern Air Lines for earmarking one of its first DC-3's for the collection, to the Civil Aeronautics Administration for reserving its famous Boeing 247-D for the Museum, and to the Martin Aircraft Company for the gift of a half-scale flight prototype of the PBM "Mariner." These will be stored temporarily by the donors.

INFORMATIONAL SERVICES

Interest in the Museum is widespread, and its services to the industry, Government departments, students, research workers, historians, authors, craftsmen, and the air fraternity in general are daily becoming more in demand as reflected in the numbers of inquiries and requests received by letter, personal visit, and telephone. Radio programs in which the Museum participated included, Information Please, We The People, and the Air Force Hour. The curator told the story of the *Swoose* over the radio both in Los Angeles and Omaha, and television programs illustrated the *Kitty Hawk*, *Gulfhawk-2*, the *NC-4*, and the Museum's model collection.

The Bureau of Ordnance, Department of the Navy, borrowed a number of the Museum's scale models to be used as patterns for research problems; the Interior Department was assisted with aeronautical details in some of its museum dioramas; the Public Schools of the District of Columbia received help in conducting their aero-

nautical courses; and Pan American Airways was loaned photographs of Santos-Dumont's airships for use in its publicity displays on Brazil. The historic sections of the Aircraft Year Book were compiled with help of the Museum staff; Bettman Archive received identification on a group of unlabeled photographs of airplanes; the Prewitt Aircraft Company used the Museum's reference files during their search for details of rotary aircraft; and the United States Chamber of Commerce and the Vallejo, Calif., museum, received assistance in displaying exhibits.

Another edition of the Handbook of the National Aircraft Collection was issued, embodying changes which bring it up to date. This is the eighth printing of 10,000 since the first issue in 1928. During the year the curator lectured on technical and historical aspects of flight and the progress of the National Air Museum to the Aero Club of Washington, the Air Transport Association, the "99ers" association of women flyers, the Washington Association of Building Superintendents, the Civitan Club, several local fraternal and church groups, and served as judge of scale-model craftsmanship at the National Capital Air Show, and at a kite contest held by local units of the Boy Scouts.

In conducting its informational services the staff acknowledges the help given by members of the "Early Birds," collectors of aeronautical photographs and clipping scrapbooks, pilots, manufacturers, airmen, and many others who donated reference material to the Museum's data files and library. These helpful source data are assembled and readily available for serious study.

SURVEY

The survey over the Nation of aeronautical materials of technical and historical significance was continued during the year. Much of the work was conducted by staff correspondence. Frequently, however, it became necessary to undertake direct investigation and study of suggested material and consultations with those acquainted with the material. It was in this connection, primarily, that the following visits away from Washington were made by the staff:

Middletown, Pa., Olmsted Air Force Base, July 23, by associate curator Robert C. Strobell, to examine a group of Japanese trophy airplanes which had been evaluated and tested.

Buffalo, N. Y., Airport, August 31, by associate curator Stephen L. Beers, to inspect two Curtiss engines used in early Naval aircraft and two French engines of World War I.

Roosevelt Field, Long Island, N. Y., and East Orange, N. J., October 11-16, by the curator, to examine a group of historic American, English, and French airplanes and to determine the availability of a Benoist airplane of 1912.

Halifax, Nova Scotia, November 9-22, by the curator, to obtain the Wright Brothers' aeroplane of 1903.

Los Angeles, Calif., Inglewood Field, and March Field, January 19-29, by the curator, to receive, recondition, and test hop the Boeing B-17-D bomber *Swoose*.

Aberdeen and Baltimore, Md., March 15, by Mr. Beers, to inspect aircraft and obtain a scale model of the Martin bomber, type MB-1 of 1918.

Jackson Center, Ohio, May 28, by Mr. Strobell, to arrange receipt and shipment of Benoist airplane.

Langley Field, Va., May 23-25, by the curator and Mr. Beers, to attend the National Advisory Committee for Aeronautics conference and inspect material of museum significance.

Miami, Fla., June 15-18, by Mr. Beers, to attend Eastern Airlines conference and inspect equipment and aircraft made available to the Museum.

Numerous trips were made by staff members between the base and field units in connection with management of the storage area and procurement and placement of accessions.

ACCESSIONS

New accessions totaled 122 objects from 40 sources. The majority of these were solicited by the Museum and involved considerable prior research by the staff to determine the significance and need of each object in the over-all picture of the history and development of aeronautics. In addition, each accession required staff attention in a variable amount in arranging for the procurement and shipment of the object and in incorporating it into the aeronautical collection.

Except where otherwise indicated the accessions received this year and listed below were entered in the Museum's records as gifts or transfers:

NATIONAL AIR MUSEUM ACCESSIONS DURING THE FISCAL YEAR ENDED JUNE 30, 1949

ABEL, A. H. (See under Port of Oakland, Board of Port Commissioners.)

ABRAMS, TALBERT (See under Abrams Instrument Corp.).

ABRAMS INSTRUMENT CORP., Lansing, Mich: (Through Talbert Abrams) The *Explorer*, single pusher monoplane with empennage extended on twin booms; believed to be the first American aircraft designed primarily for aerial mapping and survey work (N. A. M. 629, loan).

AERONCA AIRCRAFT CORP., Middletown, Ohio: (Through John A. Lawler) First production Aeronca sport plane, 1929 (N. A. M. 647, loan).

AEROPRODUCTS DIVISION, GENERAL MOTORS CORP., Dayton, Ohio: (Through W. F. Stover) Four Aeromatic propeller assembly displays illustrating types, mechanisms, and production steps (N. A. M. 651).

ALIHAN, DR. MILLA (See under Kollsman Instrument Division, Square D Co.).

ALLEN, WILLIAM B., JR. (See under U. S. Post Office Department.)

BASTOW, J. G., Oakland, Calif.: American flag insignia of the First Aero Squadron, World War I, cut from the fuselage fabric of a Salmson airplane (N. A. M. 625).

BECK, THOMAS H. (See under Crowell-Collier Publishing Co.)

BIBICKOW, WILLIAM. (See under Comet Model Airplane and Supply Co.)

- BRADLEY, R. F., San Francisco, Calif.: A framed black-and-white photograph of an early air meet and a souvenir log book of the first round-trip, trans-Pacific Pan American Airways passenger flight, 1936 (N. A. M. 636)
- BRISKIN, IRVING. (See under Columbia Pictures Corp.)
- BROOKLYN POLYTECHNIC INSTITUTE, Brooklyn, N. Y.: (Through Dr. D. G. Lockward) A 160-hp. Curtiss V-X aircraft engine used to power a Curtiss R-2 Army reconnaissance plane of 1916 (N. A. M. 631).
- CHALLINOR, G. R. (See under Kansas City, Mo., Chamber of Commerce.)
- CHANCE VUGHT AIRCRAFT, DIV. OF UNITED AIRCRAFT CORP., Stratford, Conn.: (Through John J. Hoppers) Two 1:16-scale airplane models, U. S. Navy, World War II: F4U-4 and OS2U-1 (N. A. M. 630).
- COR, DON, Williamsville, N. Y.: Two aircraft engines, rotary, French, World War I: a Clerget 9B and a Gnome "Monosoupape" (N. A. M. 655).
- COLLINS, C. S. (See under Pan American-Grace Airways, Inc.)
- COLUMBIA PICTURES CORP., Hollywood, Calif.: (Through Irving Briskin) Two scale models of Prof. John J. Montgomery's gliders reproduced for the motion picture "Gallant Journey." These show the *Santa Clara* of 1905 and the *Evergreen* of 1911 (N. A. M. 626).
- COMET MODEL AIRPLANE AND SUPPLY Co., Chicago, Ill.: (Through William Bibichkow) Wind tunnel stated by donor to be the first practical mass-produced type; for personal and classroom use; throat 14" x 22"; embodies the principles of full-scale designs; accessories are included (N. A. M. 643).
- CROWELL-COLLIER PUBLISHING Co., New York, N. Y.: (Through Thomas H. Beck) Original water-color painting by Melbourne Brindle depicting the first flight of the Wright Brothers' aeroplane at Kitty Hawk, N. C., December 17, 1903 (N. A. M. 654).
- DEHART, DANA C., San Francisco, Calif.: A major portion of a cabane strut from the Curtiss "R" which was one of the first two planes to carry scheduled air mail from New York to Chicago via Cleveland, September 5 to 17, 1918 (N. A. M. 628).
- DIETZ, GOULD (deceased), Omaha, Nebr.: Two wooden propellers: a "Paragon" 1911, used on the Army's first airship, and a "Flottorp" of early 1920 type inscribed with famous autographs (N. A. M. 644).
- DOOLITTLE, GEN. J. H., New York, N. Y.: A jagged fragment, found in China, from the right-engine nacelle of a North American B-25 "Mitchell" bomber which took part in the Tokyo raid of April 18, 1942 (N. A. M. 604).
- DOUGLAS AIRCRAFT Co., Inc., Santa Monica, Calif.: A 1:16-size scale model of the Douglas SBD Navy carrier-based dive bomber which saw extensive service in World War II (N. A. M. 620).
- FRANK, JOHN P. (See under North Carolina Granite Corp.)
- FREDERICK, D. S. (See under Rohm and Haas Co.)
- FRIES, LEONARD, London, England: A large display poster printed from the original painted by the donor, advertising the International Aviation Tournament held at Belmont Park, L. I., October 22 to 30, 1910 (N. A. M. 648).
- GILCHRIST, MRS. GUY, Dutch Flat, Calif.: The starter's flag used in the Oakland-Honolulu Dole Race, 1927. Given in memory of her brother, Maj. Edward Howard (N. A. M. 653).
- GOODWIN, CLAIRE V. (See under Port of Oakland, Board of Port Commissioners.)
- GRUMMAN, L. R. (See under Grumman Aircraft Engineering Co.)
- GRUMMAN AIRCRAFT ENGINEERING Co., Bethpage, L. I., N. Y.: (Through L. R. Grumman) Four 1:16-size scale models of Grumman aircraft, U. S. Navy, World War II: an F3F biplane fighter, an F4F "Wildcat," a TBM "Avenger" torpedo bomber, and an F7F "Tigercat" (N. A. M. 634).

GULF OIL CORP., Pittsburgh, Pa.: The *Gulfhawk-2* airplane which was flown by Maj. Alford Williams for 12 years. It illustrates the last of the Navy's biplane fighters, an F3F (N. A. M. 652).

HEFFERNAN, CAPT. J. B. (See under National Military Establishment, Department of the Navy.)

HOSFERS, JOHN J. (See under Chance Vought Aircraft, Div. of United Aircraft Corp.)

HUBBELL, CHARLES H., Cleveland, Ohio: Twelve color prints of current-design private aircraft as painted by the donor for the 1949 calendar of Thompson Products, Inc. (N. A. M. 642).

KANSAS CITY, MO., CHAMBER OF COMMERCE: (Through G. R. Challinor) A pressed-coal briquette, carried on Berlin Airlift, 1949; part of the one-millionth ton. It was mined in the Ruhr; flown from Frankfurt to Berlin and thence to Kansas City, Mo., as a feature of a ceremony acclaiming the Airlift (N. A. M. 645).

KARTVELI, A. (See under Republic Aviation Corp.)

KOLLSMAN INSTRUMENT DIVISION, SQUARE D Co., Elmhurst, N. Y.: (Through Dr. Milla Alihan) A machmeter; an instrument used to record speed in Mach Number, which expresses the speed of the aircraft in relation to the speed of sound (N. A. M. 649).

LAWLER, JOHN A. (See under Aeronca Aircraft Corp.)

LOCKWARD, DR. D. G. (See under Brooklyn Polytechnic Institute.)

MEHRHOF, KENNETH C. (See under Wright Aeronautical Corp.)

NATIONAL MILITARY ESTABLISHMENT:

Department of the Air Force. From Air Force Technical Museum, Wright-Patterson A. F. Base, Dayton, Ohio: Five 1:72-size, black plastic World War II aircraft recognition models: a C-47 two-engine transport, a PB2Y four-engine flying boat, a PBM-3 two-engine flying boat, an SB2U single-engine Navy dive bomber, and a TBD single-engine torpedo bomber (N. A. M. 633).

Department of the Navy, Washington, D. C. From Office of the Deputy Chief of Naval Operations (Air): (Through Vice Adm. John D. Price) A plaque, replica of one installed at Lisbon, Portugal, in 1946, commemorating the first trans-Atlantic flight by the *NC-4*, May 1919 (N. A. M. 646). From Office of Public Information, Bureau of Aeronautics: A Navy summer-weight flying suit and helmet, World War II type, worn by Col. Marion E. Carl, U. S. M. C., when he flew the Douglas D-558 *Skystreak* to a world's speed record of 650 m. p. h. on August 25, 1947 (N. A. M. 637). From Office of Public Relations: (Through Capt. J. B. Heffernan, U. S. N., Ret., Curator for Navy Department) Scale models of three planes used by the Navy in World War II: XPB2Y experimental version of Consolidated "Coronado" used for bombing and transport; XPBM experimental version of Martin "Mariner" used for patrol-bombing and antisubmarine service; and TBD Douglas "Devastator" carrier-based torpedo plane (N. A. M. 635, loan).

NEVIN, ROBERT S., Baltimore, Md.: A 1:24-size scale model of the Martin MB-1 twin-engined Army bomber of 1918, made by lender (N. A. M. 621, loan).

NORTH CAROLINA GRANITE CORP., Mount Airy, N. C.: (Through John P. Frank) Architects' model of the Wright Brothers Memorial on the summit of Kill Devil Hill, Kitty Hawk, N. C. (N. A. M. 638).

PAN AMERICAN-GRACE AIRWAYS, INC., New York, N. Y.: (Through C. S. Collins) The Fairchild FC-2 five-passenger cabin monoplane with which the scheduled commercial operations of Panagra System in South America were inaugurated September 1928 (N. A. M. 650).

- PERRY, KENNETH M., Washington, D. C.: A German Air Force garrison cap of the World War II period (N. A. M. 622).
- PORT OF OAKLAND, BOARD OF PORT COMMISSIONERS, Oakland, Calif.: (Through A. H. Abel) The "Diamond" airplane, identified by donors as the first airplane constructed in California (1910), and the Kemp engine used to power it; a "Wiseman-Cooke" airplane constructed by Fred Wiseman and flown by him in what was probably the first cross-country air-mail flight in America, Petaluma to Santa Rosa, Calif., February 17, 1911. This plane was also flown by Weldon Cooke (N. A. M. 639). (Through Claire V. Goodwin) A pilots' control wheel from the cockpit of Sir Charles Kingsford-Smith's *Southern Cross* airplane, first to fly from the United States to Australia, May 31-June 9, 1928; and a facsimile of the log kept by the copilot, Charles Ulm, on that flight (N. A. M. 640).
- PRICE, VICE ADM. JOHN D. (See under National Military Establishment, *Department of the Navy*.)
- REPUBLIC AVIATION CORP., Farmingdale, L. I., N. Y.: (Through A. Kartveli) three 1:16 scale models: Republic P-47-N "Thunderbolt" Air Force single-seat fighter, Republic F-84 "Thunderjet" Air Force single-seat fighter, Republic RC-3 "Seabee" all-metal, four-place amphibian personal plane; and a 1:48 scale model: Republic XF-12 "Rainbow" Air Force four-engine, long-range, high-altitude photo-reconnaissance plane (N. A. M. 641).
- ROHM AND HAAS CO., Philadelphia, Pa.: (Through D. S. Frederick) Four examples of Plexiglas forms used in construction of aircraft: a P-47 bubble canopy, an astradome, a Crocker-Wheeler nose section for B-26 aircraft, and a Sikorsky Helicopter nose (N. A. M. 627).
- SPRATT, GEORGE, Deep River, Conn.: A Curtiss V-8 air-cooled aircraft engine of about 1907, used by the donor's father in experiments with movable-wing aircraft (N. A. M. 624).
- STOVER, W. F. (See under Aeroproducts Division, General Motors Corp.)
- U. S. POST OFFICE DEPARTMENT, Washington, D. C.: (Through William B. Allen, Jr.) The pouch used to carry air mail on a flight commemorating the thirtieth anniversary of air mail; a flight was made between New York and Washington, D. C., in an Air Force P-80 jet aircraft (N. A. M. 619).
- VILAS, JACK, Chicago, Ill.: Hull of the Curtiss Flying Boat in which the donor made the first flight across Lake Michigan on July 1, 1913 (N. A. M. 632).
- WALKER, MAJ. THOMAS L., Glen Echo, Md.: Japanese equipment, World War II: an Hitachi aircraft engine from a "Cypress" biplane primary trainer, a cutaway supercharger and fuel metering device produced by Mitsubishi, and a group of five instruments also manufactured by Mitsubishi (N. A. M. 600).
- WEEMS, Capt. P. V. H., Annapolis, Md.: A collection of plotters illustrating many forms used to solve navigation problems involving position, direction, and distance (N. A. M. 656).
- WRIGHT, ORVILLE, ESTATE OF, Dayton, Ohio: The original Wright Brothers' aeroplane of 1903 (in custody for the U. S. National Museum) (U. S. N. M. 181390).
- WRIGHT AERONAUTICAL CORP., Wood-Ridge, N. J.: (Through Kenneth C. Mehrhof) Four radial aircraft engines: Curtiss "Challenger," Wright "Cyclone" 18BA, Wright "Cyclone" 14A, and Wright "Cyclone" 9GB (N. A. M. 623).
- Respectfully submitted.

CARL W. MITMAN,

Assistant to the Secretary for the National Air Museum.

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON THE CANAL ZONE BIOLOGICAL AREA

SIR: It gives me pleasure to present herewith the annual report of the Canal Zone Biological Area for the fiscal year ended June 30, 1949.

IMPROVEMENTS MADE

A new building, halfway up to the laboratory level and near the generators, was completed. The ground floor will be used largely for the woodworking machinery and carpenter shop, the upper part as living quarters for the warden-caretaker. The old cottage just below the large laboratory building, formerly occupied by the warden-caretaker, has been converted into a very desirable two-room laboratory unit. The forest is close by, making the building exceptionally suitable for observation and study of mammals and other forms.

Work on the 14,000-gallon concrete gravity-flow water tank was halted by heavy rains which made it impossible to use the truck and large concrete mixer. However, the excavation is made and the gravel and reinforcement iron are at the site; 2 or 3 weeks of dry weather will permit completion of the tank.

During the year, from allocated funds, the launch *Snook* was purchased from The Panama Canal. This is a very sturdy, well-built boat 40 feet long, with an 11-foot beam—large enough to accommodate 40 passengers. It is in very good condition and will serve even for towing.

New generators were installed during the year, providing a dependable source of electricity for continuous use.

Eight steel herbarium cases, needed for many years, have been received and the herbarium specimens transferred to them. These specimens are now in excellent condition. Eight steel storage cabinets were also received, providing dustproof storage for much of the laboratory equipment.

SCIENTISTS AND THEIR STUDIES

Twenty-nine scientists came to the laboratory during the year. Although many of them stayed only a short time, their acquaintance with the island and its facilities will no doubt bring others to the laboratory in the near future. The contribution of these scientists has added materially to our knowledge of life under tropical conditions.

Dr. Franz Schrader and Dr. Sally Hughes Schrader returned to continue their cytological studies.

Dr. Frank A. Hartman and Robert Albertin, of the Department of Physiology of the Ohio State University, spent some time on the island, and used the laboratory as their base for excursions up the Chagres River Basin and into the Volcán region of Chiriquí Province. They studied in great detail the anatomy of the adrenals in sloths and the coati-mundi while on the island. The adrenals of more than 600 vertebrates were collected during expeditions in the Republic of Panamá. Field studies were made of selected cases, and the rest of the material was taken to the island for further treatment in preparation for cytological examination later at their University laboratory. The skins of the birds obtained by them were donated to the United States National Museum. The hearts of a number of the vertebrates were sent to Dr. Struthers, of the University of Syracuse, for anatomical study of the coronaries and other blood vessels.

Dr. Hartman plans to return for a much more extensive survey, especially in relation to the effects of the male hormone, particularly in the sloth. The use of the island as a base for excursions to other nearby regions emphasizes one of the unique features of the Canal Zone Biological Area.

Dr. Per F. Scholander and Dr. Vladimir Walters, of the Arctic Research Laboratory at Point Barrow, Alaska, spent considerable time on the island studying the metabolic reactions to temperature in various animals and plants in order to obtain a tropical counterpart for the work done on Arctic forms in Alaska. A deep-freeze was used in some of their work, and the analysis of the tropical mammals and birds in cold gave just the information needed to interpret properly the findings in the Arctic. The work on the island with the deep-freeze proved of basic importance for formulating a theory on the relation between insulation and metabolism.

R. Joseph Kowal, in charge of the laboratory of the Bureau of Entomology and Plant Quarantine at Gulfport, Miss., returned in order to reexamine and evaluate the special series of termite-resistance tests initiated by him 5 years ago, including the very valuable series of soil poisons. He was assisted by Russell E. Fontaine, in charge of the insect- and pest-control work of the United States Army in the Caribbean area.

Dr. Walter Clark, in charge of the Research Laboratory of Eastman Kodak, who had come to inaugurate the large air-conditioned laboratory in the outskirts of Panama City, accompanied by Dr. Cleve C. Soper, in charge of Eastman Kodak's tropical research work here, spent several weeks on the island in connection with their corrosion and deterioration studies. As in past years, Dr. Clark took thousands

of feet of splendid motion pictures of the animal life. The work of the Eastman Kodak Company on the island, and in Panama City, is yielding most valuable data on corrosion and deterioration, as well as a better understanding of the influence of the Tropics on color film.

E. P. Killip, head curator of the department of botany, United States National Museum, spent a short time on the island, collecting material for the herbarium. He went over most of the laboratory's herbarium specimens and later will send such additional sheets as may be needed to augment or supplement the collection.

Dr. Charles C. Adams, pioneer ecologist of the Americas, was another visitor who came to the Tropics for first-hand knowledge. He stressed the value of the island for ecologists, both plant and animal, in providing an intimate acquaintance with jungle life.

Dr. and Mrs. H. N. Moldenke, of the New York Botanical Garden, visited the island after their return from the Second Pan American Botanical Congress held in Tucumán, Argentina. Dr. Moldenke's chief interest was the Verbenaceae, and he very kindly rechecked the laboratory's material in this family.

Dr. Marshall Stone, of the University of Chicago, again revisited the island for a short time.

Phil W. Longenecker, student at Colorado College, spent the month of July on the island. He made a list of 98 species of birds that he positively identified, with copious notes on their habits. His studies also included observations on a number of the mammals. In his report he states that he did not find it necessary to go far into the forest, as there was so much to see within a mile of the laboratory.

Dr. Eugene Eisenmann, of New York City, visited the island again this year to continue his ornithological studies. Dr. Eisenmann is an authority on the birds of this region. He will prepare a list, brought up to date, of the birds observed on the island.

Oliver E. Mosser, of Smithtown Branch, N. Y., came for a few days, specifically to make certain important observations of army ants for Dr. Schneirla. In addition he studied birds and mammals.

Frank W. Hunnewell and his sister Louise revisited the island and stayed several weeks, following up his botanical studies. They showed the same deep interest in the island that they had displayed ever since Dr. Barbour was actively connected with its direction.

It is a pleasure to record again a short visit by Dr. and Mrs. Matthew W. Stirling and Richard Stewart, who were in Panamá on archeological reconnaissance on behalf of the National Geographic Society and the Smithsonian Institution. Motion pictures were taken by Mr. Stewart to complete the reel covering the island.

Dr. Wetmore, Secretary of the Smithsonian, revisited the island,

at which time conferences were held with the writer on island matters, plans for the future, improvements that would be desirable. W. M. Perrygo, of the National Museum, accompanied him as assistant.

John E. Graf, Assistant Secretary of the Smithsonian Institution, spent 2 weeks on the island in June and July, examining the laboratory facilities and discussing its operations.

A. C. Langlois, of the Bahamas, whose deep interest in palms and horticulture in general are well known, was a welcome visitor for a few days, during which brief time he was able to observe the palms as they grow in their natural habitat.

W. E. Lundy, secretary-treasurer of The Panama Canal Natural History Society, a keen student of nature, spent a week on the island, and as on earlier visits prepared a detailed report of the mammals, birds, reptiles, and other forms that he saw. These yearly lists from Mr. Lundy form a very valuable record.

Miss E. Thomas and Miss Marie Weir, local naturalists of note, again revisited the island for a few profitable days.

The writer continued his special research problems, particularly the long-term termite-resistance tests, and fruit-fly populations. The large Berlese funnel has been kept in operation, and it is of interest to note the great number of species of mites, pseudoscorpions, and ants, particularly some of the very rare genera, that have been collected in this manner.

An interesting development from work done at Barro Colorado Island that should be mentioned here, since it has not previously been noted, is the availability of a phonograph record of jungle sounds by day and by night, familiar and friendly to those who know them, mysterious and sometimes fearful to the uninitiated. The work is that of Dr. Arthur A. Allen and Dr. Paul Kellogg of Cornell University who, during the war, made a long series of recordings in the jungle for training use with American troops assigned to outpost duty. A considerable part of the work was done on Barro Colorado Island, though it is only recently that the material has been released and prepared in form available to the public. The voices of howler monkeys, birds, and amphibians, reproduced faithfully by painstaking techniques, carry fully the ordinary sounds heard during the 24 hours about the Island.

MORE URGENT NEEDS

One of the most urgent needs is the fireproofing of certain structures by the use of concrete posts and concrete blocks, which could be accomplished gradually. These buildings are the Barbour and Chapman houses, the kitchen and its adjacent storerooms, and the main laboratory building.

Even more urgent is a new laboratory and storage building, which will require a small addition to the clearing back of our present laboratory site. This structure should be built with concrete posts and sills, and concrete-block sides, and should have at least six rooms. Provision should be made for the periodical use of heat in order to reduce the growth of molds. This building would provide separate rooms for the library, for scientific records, for storage of cameras and other delicate apparatus, for the herbarium, for laboratory glassware, and for chemicals. The entire building should be well ventilated, but in addition glass windows should be provided so that when necessary these can be tightly closed and heat used. High humidity, the subsequent rapid growth of fungus, and the need of protection from termites are problems of the first order in the Tropics.

Other urgent needs are steel storage cabinets, metal bookcases with closing glass fronts, metal card-index cabinets for the species index and the library index, and sectional steel letter files.

TABLE 1.—Annual rainfall, Barro Colorado Island, Canal Zone

Year	Total inches	Station average	Year	Total inches	Station average
1925.....	104. 37	-----	1937.....	124. 13	110. 12
1926.....	118. 22	113. 56	1938.....	117. 09	110. 62
1927.....	116. 36	114. 68	1939.....	115. 47	110. 94
1928.....	101. 52	111. 35	1940.....	86. 51	109. 43
1929.....	87. 84	106. 56	1941.....	91. 82	108. 41
1930.....	76. 57	101. 51	1942.....	111. 10	108. 55
1931.....	123. 30	104. 69	1943.....	120. 29	109. 20
1932.....	113. 52	105. 76	1944.....	111. 96	109. 30
1933.....	101. 73	105. 32	1945.....	120. 42	109. 84
1934.....	122. 42	107. 04	1946.....	87. 38	108. 81
1935.....	143. 42	110. 35	1947.....	77. 92	107. 49
1936.....	93. 88	108. 98	1948.....	83. 16	106. 43

TABLE 2.—Comparison of 1947 and 1948 rainfall, Barro Colorado Island, Canal Zone (inches)

Month	Total		Station average	Years of record	Excess or deficiency	Accumulated ex- cess or de- ficiency
	1947	1948				
January.....	0.40	1.84	1.84	23	-----	-----
February.....	2.14	0.19	1.22	23	-1.03	-1.03
March.....	0.54	0.17	1.36	23	-1.19	-2.22
April.....	3.00	2.92	2.81	24	+0.11	-2.11
May.....	4.82	10.80	10.85	24	-0.05	-2.16
June.....	12.06	6.32	11.10	24	-4.78	-6.94
July.....	7.83	11.45	11.61	24	-0.16	-7.10
August.....	11.78	10.46	12.44	24	-1.98	-9.08
September.....	9.53	6.72	10.27	24	-3.55	-12.63
October.....	13.17	10.74	13.07	24	-2.33	-14.96
November.....	7.25	20.33	18.84	24	+1.49	-13.47
December.....	5.63	1.22	11.62	24	-9.80	-23.27
Year.....	77.92	83.16	106.43	-----	-----	-23.27
Dry.....	6.17	5.13	7.23	-----	-----	-5.36
Wet.....	71.75	78.04	99.20	-----	-----	-17.91

FISCAL REPORT

During the fiscal year 1949, \$12,256.05 in trust funds was available. Of this amount \$11,118.90 was spent, leaving on hand only \$1,137.15 with which to face the new fiscal year. In addition to this, \$1,122.30 is still on deposit, representing local collections.

During the year only \$1,243.00 was collected as fees from scientists, as compared to \$1,907.75 last year. This decline is very largely due to the high cost of transportation to the Isthmus, which keeps many from coming. Despite the higher cost of food and other items, the laboratory has not increased its per diem charge to scientists. Those from institutions that sustain table subscriptions still receive a discount of 25 percent.

The following institutions continued their support to the laboratory through the payment of table subscriptions:

Smithsonian Institution.....	\$500. 00
American Museum of Natural History.....	300. 00
Eastman Kodak Company.....	1, 000. 00
New York Zoological Society.....	300. 00
University of Chicago.....	300. 00
Ohio State University.....	300. 00

The Forest Products Laboratory, United States Department of Agriculture, contributed \$25.00 a month as service fees for facilities furnished.

It is most gratifying to record donations from Dr. Eugene Eisenmann, Dr. Oliver P. Pearson, Mrs. Dorothy Edgerton, Miss Louise Hunnewell, Mr. Frank W. Hunnewell, and the Botanical Society of Washington.

The sum of \$5,000 was made available by the Smithsonian Institution from appropriated funds, and of this amount \$4,997.53 was used for permanent improvements. The Institution also contributed \$3,000 from its private funds, in addition to its table fees.

Respectfully submitted.

JAMES ZETEK, *Resident Manager.*

DR. ALEXANDER WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 11

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the Smithsonian library for the fiscal year ended June 30, 1949:

All the continents and most of the countries of the world were represented among the 57,671 publications received by the library during the year. These books, pamphlets, and serials were predominantly scientific and technical in character and touched all the special and related fields of interests of the Smithsonian Institution and its branches. The International Exchange Service transmitted 5,082 of them, and the rest came by mail or by other means of delivery.

Acquisitions by purchase included 1,792 volumes, three collections of pamphlets on special subjects, and subscriptions for 279 periodicals.

Gifts of 7,287 publications came from many different donors. The library owes a lasting debt of gratitude to these friends of the Institution, at home and abroad, for their generous contributions of books and papers, many of which the library would not otherwise have been able to acquire. Not yet statistically recorded in the library is the important gift of the large Ferdinand Perret Research Library of the Arts and their Affiliated Sciences, presented by Mr. Perret to the National Collection of Fine Arts.

The library's principal strength and the backbone of its usefulness lies in the large collections of publications, chiefly serials, issued by the research institutions, scientific societies, universities, academies, museums, and observatories all over the world, which the Smithsonian Institution receives in exchange for its own publications. These are the primary sources of the records of progress in science and technology, in the arts and industries. Ready access to them is indispensable to the work of the Institution. The larger number of the 17,713 periodical entries recorded during the year were these exchange publications, and many monographic works received in exchange were separately cataloged. There were 338 new exchanges arranged, and 7,008 volumes and parts needed to fill gaps in serial sets, or for special purposes, were obtained in response to 726 special requests made to the issuing agencies.

A grand total of 17,771 publications were sent to the Library of Congress. Of these, 1,978 volumes and 4,582 periodical parts were recorded as permanent additions to the great Smithsonian Deposit there. The others were foreign and domestic dissertations, documents, and miscellaneous publications of little immediate importance to the work of the Institution.

The Army Medical Library selected for transfer 859 publications no longer needed here in the sectional library of the division of medicine. Also sent to the Army Medical Library were 1,068 currently received medical dissertations and 1,927 other publications on medical subjects. A total of 1,532 publications were distributed, according to subject, among other libraries of the Government.

The cataloging of currently received publications was kept up without serious time lags and with no additions to the large "backlog" of many years standing. Records of 6,884 volumes were added to catalogs and shelflists, and 31,184 cards were filed. Work on the correlation of the central periodical entry records with those of the central catalog was begun, and 389 entries were checked, corrected, and unified. This is important work which will have far-reaching results in shortening the time of record keeping and in giving prompter service to readers.

Funds allotted for binding permitted 1,060 volumes to be prepared and sent to the Government Printing Office, but again were not sufficient to keep up with the number of volumes of serial publications completed during the year, so the "backlog" of binding continued to grow. A total of 1,026 books and pamphlets were repaired in the Museum library, but there is always much more of such work to be done than one assistant can handle, and here too there is regrettable arrearage.

Increasingly heavy demands upon reading and reference services of the library, especially from outside the Institution, were noticed throughout all the branches. Every year many visiting scientists and other scholars not only from our own but from other countries of the world make more or less extensive use of the library's resources, while letters and telephone requests for information pour in daily. Interlibrary loans of 2,619 publications to 89 different libraries were made, an increase of 732 over last year. The principal borrowers were other scientific libraries of the Government in Washington, and research institutions, museums, and universities elsewhere.

Three positions were vacant during the entire year, and the Museum library had no messenger after the end of January. The

redistribution of work assignments necessary to meet the emergencies of the situation could only be made at the expense of neglecting or postponing all but the most immediately demanding of the library's responsibilities. While every effort was made to see that services to the scientific staff suffered as little as possible, some irritating delays and inconveniences were unavoidable, most noticeably from the lack of adequate messenger service.

There was a heartening improvement in one branch of the service, made possible by the promotion of an acquisitions assistant to fill the much needed new position of assistant librarian in charge of the Astrophysical Observatory library. The position from which the promotion was made, however, is one of those still unfilled.

Even more serious than the vacancy of library positions is the housing of the library. For many years the shelves have been so badly overcrowded that the shelving of each year's acquisitions has been a matter of makeshift contrivance. To relieve the congestion double shelving—that is, two rows of books shelved one behind the other on a single shelf—has become a common practice, especially in the Natural History building. Whole sections of books in relatively less frequent use have had to be shifted to inconvenient locations in the attic stacks of the Arts and Industries building where dust and dryness are particularly bad. The generally poor arrangements of the library's quarters in all the buildings, too, and the lack of any well-equipped space for a centralized collection of the indispensable reference books needed in common by all the bureaus of the Institution are handicaps to the kind of library service that should be expected in the Smithsonian Institution. Until some practical means can be found to remedy these and many related bad housing conditions, progressive deterioration of books and library service alike is inevitable.

SUMMARIZED STATISTICS

Accessions

	Volumes	Total recorded volumes June 30, 1949
Astrophysical Observatory (including Radiation and Organisms).....	486	13, 073
Bureau of American Ethnology.....	112	34, 719
National Air Museum.....	23	40
National Collection of Fine Arts.....	347	11, 791
National Museum.....	2, 775	243, 666
National Zoological Park.....	13	4, 193
Smithsonian Deposit at the Library of Congress.....	1, 978	580, 651
Smithsonian Office.....	466	33, 073
Total.....	6, 300	921, 206

Neither incomplete volumes of periodicals nor separates and reprints from periodicals are included in these figures.

Exchanges

New exchanges arranged.....	338
104 of these were assigned to the Smithsonian Deposit in the Library of Congress.	
Specially requested publications received.....	7, 008
923 of these were obtained to fill gaps in the Smithsonian Deposit sets	

Cataloging

Volumes and pamphlets cataloged.....	6, 884
Cards added to catalogs and shelflists.....	31, 184

Periodicals

Periodical parts entered.....	17, 713
Of these, 4,582 were sent to the Smithsonian Deposit at the Library of Congress.	

Circulation

Loans of books and periodicals.....	11, 689
This figure does not include the intramural circulation of books and periodicals filed in 31 sectional libraries, of which no count is kept.	

Binding

Volumes sent to the bindery.....	1, 060
Volumes repaired in the Museum.....	1, 026

Respectfully submitted.

LEILA F. CLARK, *Librarian.*

Dr. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 12

REPORT ON PUBLICATIONS

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ended June 30, 1949.

The Institution published during the year 14 papers and title pages and tables of contents for 2 volumes in the Smithsonian Miscellaneous Collections, 1 Annual Report of the Board of Regents and pamphlet copies of 18 articles in the Report appendix, 1 Annual Report of the Secretary, and a new edition of 1 special publication, and a reprint of another.

The United States National Museum issued 1 Annual Report, 25 Proceedings papers, 3 Bulletins, and 2 papers in the Bulletin series, Contributions from the United States National Herbarium.

The Bureau of American Ethnology issued 1 Annual Report and 2 Publications of the Institute of Social Anthropology.

The Freer Gallery of Art issued 1 publication in its Occasional Papers series.

Of the publications there were distributed 267,491 copies, which included 15 volumes and separates of Smithsonian Contributions to Knowledge, 27,438 volumes and separates of Smithsonian Miscellaneous Collections, 26,302 volumes and separates of Smithsonian Annual Reports, 3,696 War Background Studies, 6,361 Smithsonian special publications, 38 reports of the Harriman Alaska Expedition, 66,459 volumes and separates of National Museum publications, 12,787 publications of the Bureau of American Ethnology, 6,873 Publications of the Institute of Social Anthropology, 10 catalogs of the National Collection of Fine Arts, 603 volumes and pamphlets of the Freer Gallery of Art, 38 Annals of the Astrophysical Observatory, 1,389 Reports of the American Historical Association, and 5,014 miscellaneous publications not printed by the Smithsonian Institution (mostly Survival Manuals.)

In addition, 87,715 Guide Books, 22,573 natural history and art post cards, 162 sets of North American Wild Flowers, and 18 Pitcher Plants volumes were distributed.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

In this series there were issued title page and table of contents of volume 107, 7 papers and title page and table of contents of volume 110, and 7 papers in volume 111, as follows:

VOLUME 107

Title page and table of contents. (Publ. 3949.) Sept. 3, 1948.

VOLUME 110

No. 7. Gustavus Schon's portraits of Flathead and Pend d'Oreille Indians, 1854, by John C. Ewers. 68 pp., 22 pls. (Publ. 3941.) Nov. 26, 1948.

No. 8. The behavior of barometric pressure during and after solar particle invasions and solar ultraviolet invasions, by B. Duell and G. Duell. 34 pp., 21 figs. (Publ. 3942.) Aug. 5, 1948.

No. 9. A new genus and five new species of American fishes, by Samuel F. Hildebrand. 15 pp., 6 figs. (Publ. 3943.) July 28, 1948.

No. 10. The feeding organs of Arachnida, including mites and ticks, by R. E. Snodgrass. 93 pp., 29 figs. (Publ. 3944.) Aug. 18, 1948.

No. 11. The Smithsonian standard pyrheliometry, by C. G. Abbot. 4 pp. (Publ. 3945.) Aug. 5, 1948.

No. 12. The Drum Mountains, Utah, meteorite, by E. P. Henderson and S. H. Perry. 7 pp., 5 pls. (Publ. 3946.) Sept. 3, 1948.

No. 13. Contributions to the anthropology of the Soviet Union, by Henry Field. 244 pp., 5 pls. (Publ. 3947.) Dec. 22, 1948.

Title page and table of contents. (Publ. 3984.) May 12, 1949.

VOLUME 111

No. 1. Mirandolle's forest falcon, by Herbert Friedmann. 4 pp., 2 pls. (Publ. 3948.) Sept. 22, 1948.

No. 2. Prehistory and the Missouri Valley development program. Summary report on the Missouri River Basin Archeological Survey in 1947, by Waldo R. Wedel. 52 pp., 8 pls. (Publ. 3950.) Nov. 23, 1948.

No. 3. Further new Cambrian bellerophon gastropods, by J. Brookes Knight. 6 pp., 1 pl. (Publ. 3951.) Dec. 24, 1948.

No. 4. Type material of the species of clerid beetles described by Charles Schaeffer, by Edward A. Chapin. 12 pp. (Publ. 3977.) Apr. 5, 1949.

No. 5. 1948-1949 report on the 27.0074-day cycle in Washington precipitation, by C. G. Abbot. 2 pp. (Publ. 3980.) Mar. 8, 1949.

No. 6. A prediction of Washington temperature 1948 (made January 1948), by C. G. Abbot. 6 pp., 1 fig. (Publ. 3982.) Mar. 8, 1949.

No. 7. Montezuma solar-constant values and their periodic variations, by C. G. Abbot. 13 pp., 3 figs. (Publ. 3981.) Apr. 19, 1949.

SMITHSONIAN ANNUAL REPORT

Report for 1947.—The complete volume of the Annual Report of the Board of Regents for 1947 was received from the Public Printer December 15, 1948:

Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and condition of the Institution for the year ended June 30, 1947. ix+471 pp., 65 pls., 67 figs. (Publ. 3921.)

The general appendix contained the following papers (Publs. 3922-3939):

Large sunspots, by Seth B. Nicholson.

Atomic energy, by A. E. Johns.

Telegraphy—pony express to beam radio, by George C. Hillis.

Plutonium and other transuranium elements, by Glenn T. Seaborg.

The use of isotopes as tracers, by A. H. W. Aten, Jr., and F. A. Heyn.

Silicones—a new continent in the world of chemistry, by S. L. Bass.

New products of the petroleum industry, by Hugh W. Field.

The tsunami of April 1, 1946, in the Hawaiian Islands, by G. A. Macdonald, F. P. Shepard, and E. C. Cox.

Drowned ancient islands of the Pacific basin, by H. H. Hess.

The biology of Bikini Atoll, with special reference to the fishes, by Leonard P. Schultz.

The senses of bats, by Brian Vesey-FitzGerald

Mollusks and medicine in World War II, by R. Tucker Abbott.

Some remarks on the influence of insects on human welfare, by Carl D. Duncan.

Mosquito control tests from the Arctic to the Tropics, by H. H. Stage.

The primary centers of civilization, by John R. Swanton.

The Ryukyu people: A cultural appraisal, by Marshall T. Newman and Ransom L. Eng.

Puzzle in Panama, by Waldo G. Bowman.

Comparison of propeller and reaction-propelled airplane performances, by Benson Hamlin and F. Spenceley.

Report for 1948.—The Report of the Secretary, which included the financial report of the executive committee of the Board of Regents, and which will form part of the Annual Report of the Board of Regents to Congress, was issued January 13, 1949:

Report of the Secretary of the Smithsonian Institution and financial report of the executive committee of the Board of Regents for the year ended June 30, 1948. ix+158 pp., 4 pls., 1 chart. (Publ. 3952.) 1948.

The Report volume for 1948, containing the general appendix, was in press at the close of the year.

SPECIAL PUBLICATIONS

National Aircraft Collection, by Paul Edward Garber. Eighth edition 44 pp., illus. (Publ. 3979.) May 2, 1949.

The following special publication was reprinted:

Brief Guide to the Smithsonian Institution. Seventh edition. 80 pp., illus. Dec. 13, 1948.

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum has continued during the year under the immediate direction of the editor, Paul H. Oehser. There were issued 1 Annual Report, 25 Proceedings papers, 3 Bulletins,

and 2 separate papers in the Bulletin series, Contributions from the United States National Museum.

REPORT

Report on the progress and condition of the United States National Museum for the year ended June 30, 1948. iii+127 pp. Jan. 25, 1949.

PROCEEDINGS: VOLUME 98

No. 3222. A potential snail host of Oriental schistosomiasis in North America (*Pomatiopsis lapidaria*), by R. Tucker Abbott. Pp. 57-68, pls. 3, 4, figs. 10, 11. July 2, 1948.

No. 3224. The serphoid Hymenoptera of the family Roproniidae, by Henry Townes. Pp. 85-89, fig. 12. July 8, 1948.

No. 3225. Parasitic wasps of the genus *Trimorus* in North America, by Robert M. Fouts. Pp. 91-148, figs. 13-15. Aug. 19, 1948.

No. 3226. New pemphilidine wasps from southern Nigeria, by V. S. L. Pate. Pp. 149-162, fig. 16. Oct. 19, 1948.

No. 3227. The butterflies of the Admiralty Islands, by Warren Herbert Wagner, Jr., and David F. Grether. Pp. 163-186, pls. 11-13. Dec. 7, 1948.

No. 3228. Flies of the family Stratiomyidae of the Solomon Islands, by Maurice T. James. Pp. 187-213. Nov. 9, 1948.

No. 3229. Cyprinodont fishes of the genus *Fundulus* in the West Indies, with description of a new subspecies from Cuba, by Luis René Rivas. Pp. 215-222, pl. 14. Oct. 19, 1948.

No. 3230. A new crayfish of the genus *Cambarus* from Texas, with notes on the distribution of *Cambarus fodiens* (Cottle), by Horton H. Hobbs, Jr. Pp. 223-231, fig. 17. Nov. 16, 1948.

No. 3231. Report on the Pycnogonida collected by the *Albatross* in Japanese waters in 1900 and 1906, by Joel W. Hedgpeth. Pp. 233-321, figs. 18-51. Mar. 14, 1949.

No. 3232. Mammals of northern Colombia. Preliminary report No. 4: Monkeys (Primates), with taxonomic revisions of some forms, by Philip Hershkovitz. Pp. 323-427, pls. 15-17, figs. 52-59. May 10, 1949.

No. 3233. Bees from Central America, principally Honduras, by T. D. A. Cockerell. Pp. 429-490. May 25, 1949.

No. 3234. A generic revision of the treehoppers of the tribe Ceresini in America north of Mexico, based on a study of the male genitalia, by John S. Caldwell. Pp. 491-521, pls. 18-23. May 10, 1949.

VOLUME 99

No. 3235. A further contribution to the ichthyology of Venezuela, by Leonard P. Schultz. Pp. 1-211, pls. 1-3, figs. 1-20. May 10, 1949.

No. 3236. The weevils of the genus *Tachygonus* in the United States National Museum, with descriptions of new species, by Oscar Monte. Pp. 213-227, figs. 21-32. May 25, 1949.

No. 3237. The species of ichneumon-flies of the genus *Cardiochiles* occurring in America north of Mexico, by Ying-Tou Mao. Pp. 229-266, pls. 4-5. Mar. 21, 1949.

No. 3238. A revision of the mites of the family Cheyletidae in the United States National Museum, by Edward W. Baker. Pp. 267-320, pls. 6-17. Apr. 14, 1949.

No. 3239. A new species of copepod of the genus *Corycaeus* from the North American coast, by Mildred Stratton Wilson. Pp. 321-326, pl. 18. June 10, 1949.

No. 3240. New buprestid beetles from Mexico, Central and South America, and the West Indies, by W. S. Fisher. Pp. 327-351. Apr. 26, 1949.

No. 3241. The Pima County (Arizona) meteorite, by E. P. Henderson and Stuart H. Perry. Pp. 353-355, pls. 19, 20. Apr. 27, 1949.

No. 3242. The Linwood (Nebraska) meteorite, by E. P. Henderson and Stuart H. Perry. Pp. 357-360, pls. 21-24. Apr. 27, 1949.

No. 3243. The Nearctic species of the family Stephanidae (Hymenoptera), by Henry Townes. Pp. 361-370, pl. 25. June 10, 1949.

No. 3244. Nine new xystodesmid millipeds from Virginia and West Virginia, with records of established species, by Richard L. Hoffman. Pp. 371-389, pls. 26, 27. June 14, 1949.

No. 3245. A review of the copepod genus *Paranthessius* Claus, by Paul L. Illg. Pp. 391-428, figs. 33-37. May 10, 1949.

No. 3246. Mammals of northern Colombia. Preliminary report No. 5: Bats (Chiroptera), by Philip Hershkovitz. Pp. 429-454, fig. 38. May 10, 1949.

No. 3247. New species and records of staphylinid beetles from Formosa, Japan, and South China, by Malcolm Cameron. Pp. 455-477. June 14, 1949.

BULLETINS

No. 100, vol. 14, pt. 3. Report on the Echinoidea collected by the United States Fisheries steamer *Albatross* during the Philippine Expedition, 1907-1910. Part 3: The Echinocidae, Echinolampadidae, Clypeastridae, Arachnoididae, Laganidae, Fibulariidae, Urechinidae, Echinocorythidae, Palaeostomatidae, Micrasteridae, Palaeopneustidae, Hemiasteridae, and Spatangidae, by Theodor Mortensen. Pp. i-iii, 93-140. Oct. 29, 1949.

No. 195. Life histories of North American nuthatches, wrens, thrashers, and their allies. Order Passeriformes, by Arthur Cleveland Bent. Pp. i-xi, 1-475, 90 pls. July 7, 1948.

No. 196. Life histories of North American thrushes, kinglets, and their allies. Order Passeriformes, by Arthur Cleveland Bent. Pp. i-viii, 1-454, 51 pls. June 28, 1949.

CONTRIBUTIONS FROM THE UNITED STATES NATIONAL HERBARIUM VOLUME 29

Part 5. A revision of *Macrocarpaea*, a Neotropical genus of shrubby gentians, by Joseph Ewan. Pp. i-vii, 209-249, pls. 1-5. Aug. 23, 1948.

Part 6. New grasses from Honduras, Colombia, Venezuela, Ecuador, Bolivia, and Brazil, by Jason R. Swallen. Pp. i-iii, 251-276. Feb. 18, 1949.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau continued under the immediate direction of the editor, M. Helen Palmer. During the year the following publications were issued:

REPORT

Sixty-fifth Annual Report of the Bureau of American Ethnology, 1947-1948. 32 pp.

PUBLICATIONS OF THE INSTITUTE OF SOCIAL ANTHROPOLOGY

No. 8. Sierra Popoluca speech, by Mary L. Foster and George M. Foster. 45 pp.

No. 9. The Terena and the Caduveo of southern Mato Grosso, Brazil, by Kalervo Oberg. 72 pp., 24 pls., 4 maps, 2 charts.

PUBLICATIONS OF THE FREER GALLERY OF ART

OCCASIONAL PAPERS: VOLUME 1

No. 2. Paintings, pastels, drawings, prints, and copper plates by and attributed to American and European artists, together with a list of original Whistleriana, in the Freer Gallery of Art, by Burns A. Stubbs. 152 pp., 20 pls. (Publ. 3905.) Aug. 6, 1948.

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the Association to the Secretary of the Smithsonian Institution and are communicated by him to Congress, as provided by the act of incorporation of the Association. The following report volumes were issued this year:

Annual Report of the American Historical Association for 1943. Vol. 2, Writings on American History, 1939 and 1940.

Annual Report of the American Historical Association for 1945:

Vol. 2, Spain in the Mississippi Valley, 1765-1794. Pt. 1, The Revolutionary period, 1765-1781.

Vol. 3, Spain in the Mississippi Valley, 1765-1794. Pt. 2, Postwar decade, 1782-1791.

Annual Report of the American Historical Association for 1947. Vol. 1, Proceedings.

The following were in press at the close of the fiscal year; Annual Report of the American Historical Association for 1945. Vol. 4, Spain in the Mississippi Valley, 1765-1794. Pt. 3, Problems of frontier defense, 1792-1794; Annual Report of the American Historical Association for 1948. Vol. 1, Proceedings.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Fifty-first Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, February 9, 1949.

APPROPRIATION FOR PRINTING AND BINDING

The congressional appropriation for printing and binding for the past year was entirely obligated at the close of the year. The appropriation for the coming fiscal year ending June 30, 1950, totals \$103,000, allotted as follows:

General administration (Annual Report of the Board of Regents; Annual Report of the Secretary)	\$18, 500
National Museum.....	36, 200
Bureau of American Ethnology.....	21, 500
National Air Museum.....	3, 000
Service division (Annual Report of the American Historical Association; blank forms; binding; Museum print shop)	23, 800
	<hr/>
	103, 000

Respectfully submitted.

W. P. TRUE, *Chief, Editorial Division.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSON- IAN INSTITUTION

FOR THE YEAR ENDED JUNE 30, 1949

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution, together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

SMITHSONIAN ENDOWMENT FUND

The original bequest of James Smithson was £104,960 8s 6d—\$508,318.46. Refunds of money expended in prosecution of the claim, freights, insurance, etc., together with payment into the fund of the sum of £5,015, which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of \$550,000.

Since the original bequest, the Institution has received gifts from various sources, the income from which may be used for the general work of the Institution. These, including the original bequest, plus savings, are listed below, together with the income for the present year.

ENDOWMENT FUNDS

(Income for unrestricted use of the Institution)

Partly deposited in United States Treasury at 6 percent and partly invested in stocks, bonds, etc.

	Investment	Income present year
Parent fund (original Smithson bequest, plus accumulated savings).....	\$728, 878. 50	\$43, 710. 56
Subsequent bequests, gifts, etc., partly deposited in the U. S. Treasury and partly invested in the consolidated fund:		
Avery, Robert S., and Lydia, bequest fund.....	54, 072. 23	2, 527. 92
Endowment fund.....	337, 808. 80	14, 220. 74
Habel, Dr. S., bequest fund.....	500. 00	20. 00
Harbenberg, George F. and Caroline, bequest fund.....	4, 080. 11	171. 87
Hamilton, James, bequest fund.....	2, 909. 54	167. 26
Henry, Caroline, bequest fund.....	1, 228. 97	51. 70
Hodgkins, Thomas G., (general) gift.....	146, 418. 02	8, 241. 27
Porter, Henry Kirke, memorial fund.....	280, 547. 80	12, 238. 39
Rhoes, William Jones, bequest fund.....	1, 066. 95	55. 65
Sanford, George H., memorial fund.....	2, 003. 12	104. 04
Witherspoon, Thomas A., memorial fund.....	130, 922. 14	5, 514. 70
Special fund, stock in reorganized closed banks.....	2, 280. 00	100. 00
Total.....	973, 638. 68	43, 483. 84
Grand total.....	1, 702, 517. 18	87, 194. 10

The Institution holds also a number of endowment gifts, the income of each being restricted to specific use. These, plus accretions to date, are listed below, together with income for the present year.

	Investment	Income present year
Abbott, William L., fund, for investigations in biology.....	\$102,949.49	\$4,276.13
Arthur, James, fund, for investigations and study of the sun and lecture on same.....	40,573.48	1,709.05
Bacon, Virginia Purdy, fund, for traveling scholarship to investigate fauna of countries other than the United States.....	50,827.58	2,140.95
Baird, Lucy H., fund, for creating a memorial to Secretary Baird.....	24,426.07	1,028.88
Barstow, Frederick D., fund, for purchase of animals for Zoological Park.....	1,014.26	42.73
Canfield Collection fund, for increase and care of the Canfield collection of minerals.....	38,801.89	1,634.41
Casey, Thomas L., fund, for maintenance of the Casey collection, and promotion of researches relating to Coleoptera.....	9,305.19	391.95
Chamberlain, Francis Lea, fund, for increase and promotion of Isaac Lea collection of gems and mollusks.....	28,569.00	1,203.39
Eickemeyer, Florence Brevoort, fund, for preservation and exhibition of the photographic collection of Rudolph Eickemeyer, Jr.....	514.66	21.68
Hillyer, Virgil, fund, for increase and care of Virgil Hillyer collection of lighting objects.....	6,667.55	280.85
Hitchcock, Dr. Albert S., library fund, for care of Hitchcock Agrostological Library.....	1,600.81	67.44
Hodgkins fund, specific, for increase and diffusion of more exact knowledge in regard to nature and properties of atmospheric air.....	100,000.00	6,000.00
Hrdlička, Aleš and Marie, fund, to further researches in physical anthropology and publication in connection therewith.....	18,657.75	785.91
Hughes, Bruce, fund, to found Hughes alcove.....	19,418.98	817.96
Long, Annette and Edith C., fund, for upkeep and preservation of Long collection of embroideries, laces, etc.....	550.87	23.20
Maxwell, Mary E., fund, for care, etc., of Maxwell collection.....	10,001.07	421.29
Myer, Catherine Walden, fund, for purchases of first-class works of art for the use and benefit of the National Collection of Fine Arts.....	19,230.71	810.04
Strong, Julia D., bequest fund, for benefit of the National Collection of Fine Arts.....	10,143.51	427.27
Pell, Cornelia Livingston, fund, for maintenance of Alfred Duane Pell collection.....	7,519.99	310.76
Poore, Lucy T. and George W., fund, for general use of the Institution when principal amounts to \$250,000.....	114,451.10	5,478.83
Rathbun, Richard, memorial fund, for use of division of U. S. National Museum containing Crustacea.....	10,790.25	454.51
Reid, Addison T., fund, for founding chair in biology, in memory of Asher Tunis.....	30,263.63	1,506.88
Roebbling Collection fund, for care, improvement, and increase of Roebbling collection of minerals.....	122,439.01	5,157.39
Rollins, Miriam and William, fund, for investigations in physics and chemistry.....	95,262.90	4,008.69
Smithsonian employees' retirement fund.....	34,364.54	1,447.51
Springer, Frank, fund, for care, etc., of Springer collection and library.....	18,192.99	760.33
Walcott, Charles D. and Mary Vaux, research fund, for the development of geological and paleontological studies and publishing results thereof.....	381,676.84	18,717.37
Younger, Helen Walcott, fund, held in trust.....	46,599.76	3,710.66
Zerbee, Frances Brincklé, fund, for endowment of aquaria.....	962.30	40.53
Total.....	1,345,776.78	63,694.69

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other Oriental objects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for the construction of a building to house the collection, and finally in his will, probated November 6, 1919, he provided stock and securities to the estimated value of \$1,958,591.42, as an endowment fund for the operation of the Gallery.

The above fund of Mr. Freer was almost entirely represented by 20,465 shares of stock in Parke, Davis & Co. As this stock advanced in value, much of it was sold and the proceeds reinvested so that the fund now amounts to \$6,092,775.69 in a selected list of securities classified later.

SUMMARY OF ENDOWMENTS

Invested endowment for general purposes.....	\$1, 702, 517. 18
Invested endowment for specific purposes other than Freer Endowment.....	1, 345, 776. 78
Total invested endowment other than Freer endowment..	3, 048, 293. 96
Freer invested endowment for specific purposes.....	6, 092, 775. 69
Total invested endowment for all purposes.....	9, 141, 069. 65

CLASSIFICATION OF INVESTMENTS

Deposited in the U. S. Treasury at 6 percent per annum, as authorized in the U. S. Revised Statutes, sec. 5591.....	\$1, 000, 000. 00
Investments other than Freer endowment (cost or market value at date acquired):	
Bonds	\$683, 834. 86
Stocks	1, 245, 283. 78
Real estate and first-mortgage notes	62, 790. 83
Uninvested capital.....	56, 384. 49
	2, 048, 293. 96
Total investments other than Freer endowment.....	3, 048, 293. 96
Investment of Freer endowment (cost or market value at date acquired):	
Bonds.....	\$2, 925, 452. 84
Stocks	3, 133, 881. 17
Uninvested capital.....	33, 441. 68
	6, 092, 775. 69
Total investments.....	9, 141, 069. 65

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING FISCAL YEAR 1949¹

Cash balance on hand June 30, 1948.....	\$563, 847. 37
Receipts other than Freer endowment:	
Income from investments.....	\$156, 219. 10
Gifts and contributions.....	48, 143. 71
Sales of publications.....	33, 281. 09
Miscellaneous.....	11, 566. 10
Total receipts other than Freer endowment.....	249, 210. 00
Receipts from Freer endowment:	
Income from investments.....	\$282, 265. 48
Total receipts from Freer endowment.....	282, 265. 48
Total.....	1, 095, 322. 85
Disbursements other than Freer endowment:	
Administration.....	\$43, 422. 75
Publications.....	45, 618. 12
Library.....	3, 977. 10
Buildings—care, repairs, alterations.....	136. 00
Custodian fees, etc.....	3, 293. 15
Miscellaneous.....	3, 822. 77
Researches.....	127, 412. 84
Smithsonian Retirement System.....	3, 608. 28
Purchases of securities (net).....	4, 508. 63
Total disbursements other than Freer endowment.....	235, 799. 64
Disbursements from Freer endowment:	
Salaries.....	\$83, 480. 37
Purchases for collections.....	125, 050. 00
Custodian fees, etc.....	10, 858. 00
Miscellaneous.....	26, 594. 80
Purchases of securities (net).....	80, 631. 18
Total disbursements from Freer endowment.....	326, 614. 35
Investment of current funds in U S. Bonds.....	2, 578. 13
Total disbursements.....	564, 992. 12
Cash balance June 30, 1949.....	530, 330. 73
Total.....	1, 095, 322. 85

¹ This statement does not include Government appropriations under the administrative charge of the Institution.

ASSETS

Cash:

United States Treasury current account.....	\$360, 201. 95
In banks and on hand.....	170, 128. 78

530, 330. 73

Less uninvested endowment funds.....

89, 826. 17

\$440, 504. 56

Travel and other advances..... 11, 585. 42

Cash invested (U. S. Treasury notes)..... 502, 815. 37

\$954, 905. 35

Investments—at book value:

Endowment funds:

Freer Gallery of Art:

Stocks and bonds... \$6, 059, 334. 01

Uninvested capital... 33, 441. 68

6, 092, 775. 69

Investments at book value other than Freer:

Stocks and bonds..... \$1, 929, 118. 64

Real estate and mortgage notes..... 62, 790. 83

Uninvested capital..... 56, 384. 49

Special deposit in U. S.

Treasury. Interest at

6 percent..... 1, 000, 000. 00

3, 048, 293. 96

9, 141, 069. 65

10, 095, 975. 00

UNEXPENDED FUNDS AND ENDOWMENTS

Unexpended funds:

Income from Freer Gallery of Art endowment..... 393, 411. 62

Income from other endowments:

Restricted..... \$187, 425. 28

General..... 85, 599. 74

273, 025. 02

Gifts and grants..... 288, 468. 71

954, 905. 35

Endowment funds:

Freer Gallery of Art..... \$6, 092, 775. 69

Other:

Restricted..... \$1, 345, 776. 78

General..... 1, 702, 517. 18

3, 048, 293. 96

9, 141, 069. 65

10, 095, 975. 00

The practice of maintaining savings accounts in several of the Washington banks and trust companies has been continued during the past year, and interest on these deposits amounted to \$824.74.

In many instances, deposits are made in banks for convenience in collection of checks, etc., and later such funds are withdrawn and deposited in the United States Treasury.

Disbursement of funds is made by check signed by the Secretary of the Institution and drawn on the United States Treasury.

The foregoing report relates only to the private funds of the Institution.

The Institution gratefully acknowledges gifts from the following:

American Philosophical Society, for Iroquois research.

W. W. Corcoran, for B. F. Starr.

Eickemeyer Estate, for preservation, etc., of Rudolph Eickemeyer photographic collection.

E. P. Killip, for use of Department of Botany.

National Academy of Sciences, for study of flora of Okinawa.

National Geographic Society, expedition to western Panamá.

Research Corporation.

John A. Roebling, additional contribution for researches in radiation.

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1949:

Salaries and expenses.....	\$2, 259, 000. 00
National Zoological Park.....	528, 848. 00

In addition, funds were transferred from other Departments of the Government for expenditure under direction of the Smithsonian Institution as follows:

Cooperation with the American Republics (transfer from the State Department)	\$97, 900. 00
Working Fund, transferred from the National Park Service, Interior Department, for archeological investigations in River Basins throughout the United States.....	\$118, 500. 00

The Institution also administers a trust fund for partial support of the Canal Zone Biological Area, located on Barro Colorado Island in the Canal Zone.

The report of the audit of the Smithsonian private funds follows:

SEPTEMBER 14, 1949.

TO THE BOARD OF REGENTS,

SMITHSONIAN INSTITUTION,

Washington 25, D. C.

We have examined the accounts of the Smithsonian Institution relative to its private endowment funds and gifts (but excluding the National Gallery of Art and other departments, bureaus, or operations administered by the Institution under Federal appropriations) for the year ended June 30, 1949. Our examination was made in accordance with generally accepted auditing standards, and

accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

The Institution maintains its accounts on a cash basis and does not accrue income and expenses. Land, buildings, furniture, equipment, works of art, living and other specimens and certain sundry property are not included in the accounts of the Institution.

In our opinion, the accompanying financial statements present fairly the position of the private funds and the cash and investments thereof of the Smithsonian Institution at June 30, 1949 (excluding the National Gallery of Art and other departments, bureaus or operations administered by the Institution under Federal appropriations) and the cash receipts and disbursements for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

PEAT, MARWICK, MITCHELL & Co.

Respectfully submitted.

ROBERT V. FLEMING,
VANNEVAR BUSH,
CLARENCE CANNON,
Executive Committee.

GENERAL APPENDIX
TO THE
SMITHSONIAN REPORT FOR 1949

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ADVERTISEMENT

The object of the **GENERAL APPENDIX** to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the Secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report of 1889, a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1949.

THE FORMATION OF STARS

BY LYMAN SPITZER, JR.
Princeton University Observatory

[With 2 plates]

If research in astronomy had stopped in 1913, our knowledge of stellar evolution today would be in a satisfactory state. At that time astronomers had a plausible theory of a star's life cycle. Einstein's theory of relativity, advanced only a few years before, showed that mass and energy were interchangeable. It was therefore natural for astronomers to assume that stars were formed as large massive bodies which through successive century after century continued to radiate away matter. Ultimately most of the matter in a star, according to this picture, would be radiated away as light and heat. In this way all the stars, despite their large differences in mass, formed part of the same evolutionary sequence.

Unfortunately, this simple, sweeping, and satisfying picture became discredited by additional information, both astronomical and physical. On the astronomical side, evidence began to accumulate that the universe has not lasted long enough for most stars to radiate away much of their matter. The expansion of the universe, the presence of uranium on the earth, the existence of certain relatively transitory clusters of stars, all indicate that something happened about 3 billion years ago. If the universe was not created then, it was certainly very extensively reorganized; some sort of cosmic explosion apparently took place at that time. Since the sun, a fairly typical star, would require many hundreds of billions of years to radiate an appreciable fraction of its mass, its total mass has obviously not changed appreciably within this last few billion years.

On the physical side, nuclear physicists have learned a great deal about the specific processes by which matter can be converted into energy. The only known process of importance which can liberate energy inside a star is the combination of four hydrogen atoms to form a helium atom. Calculations carried out by the nuclear physicist, Prof. Hans Bethe, show that in the stars this process occurs through the catalytic action of carbon and nitrogen nuclei. Since

¹ Reprinted by permission from *Physics Today*, vol. 1, No. 5, September 1948.

four hydrogen atoms weigh 0.7 percent more than one helium atom, the additional mass is released as energy and can be radiated by the star. Even if a star is originally all hydrogen, the total mass radiated can evidently not exceed a very small fraction of the mass of the star.

As a result of these findings we now know that the universe has apparently not lasted long enough in its present form for stars to radiate much of their mass, and in any case there seems to be no physical process by which a star could radiate away most of its matter even if there were time enough. We are forced to conclude that the present variety of stars in the sky is the result of the original method of star formation rather than of any evolutionary process. And the formation of stars in general is still a closed book, since the explosion of the universe a few billion years ago has so far defied any attempts at detailed analysis. It is even possible that the basic laws of nature may have been quite different at that time. Thus our research in the direction of general stellar evolution reminds one of Browning's philosopher, who had

. . . written three books on the soul,
Proving absurd all written hitherto
And putting us to ignorance again.

SUPERGIANT STARS

While the origin of the universe is still beyond our understanding, some progress has been made in explaining the origin of a certain class of stars, which may have been created relatively recently. A supergiant star is one which radiates light and heat some ten thousand times as strongly as our own sun. There are not many of these stars, but in a galaxy of many billions of lesser stars they stand out in the same way that a searchlight stands out from a swarm of fireflies. These stars are burning their candle at both ends and they cannot last very long, astronomically speaking. Within a mere hundred million years, such a star must burn all its hydrogen into helium. There is no known way in which a star can remain dark for a long period of time and then suddenly start shining. We conclude that these supergiant stars have formed within the last hundred million years—less than a tenth of the age of the universe.

Of course, it is possible that nuclear physicists have overlooked some important process by which a star can radiate a much larger fraction of its mass than the hydrogen-into-helium process liberates. This does not seem very likely, since the energies with which the atoms hit each other inside a star average only a few thousand electron volts—a small fraction of the energies developed in such atom-busting devices as the cyclotron and synchrotron—and since the nuclear reactions produced at low energies have been fairly well explored in the laboratory.

If it is assumed that these stars have in fact been formed within the last hundred million years, the mechanism for this formation is a problem which astronomers may hope to investigate with some hope of success. Within this interval, conditions in the universe have apparently not changed very much and an examination of the universe about us may actually indicate how supergiant stars have formed in the past, and may even be forming at the present time.

CLOUDS—THE CLUE

The clouds of matter which float about between the stars are an obvious source of material for star formation. Recent investigations show that these clouds are in fact so closely associated with supergiant stars that a physical connection between them seems very likely.

In brief, the observations indicate that supergiant stars are found only in those aggregations of stars where interstellar clouds of matter are also present. More specifically, observations of stellar galaxies, each one a million or so light-years away and each, like our own galaxy, containing many billions of stars, show that supergiant stars are found only in spiral galaxies. These spiral systems, like the huge galaxy in which our sun is located, are flattened, disk-shaped systems some hundred thousand light-years in diameter, each one rotating about an axis perpendicular to the plane of its disk. A typical spiral galaxy is shown in plate 1, figure 2. The characteristic feature of these systems, after which they are named, is the presence of a pair of arms which apparently come out of the central nucleus and wind around the system.

In the elliptical galaxies—which are not rotating so rapidly, are not so flattened, and show no spiral structure—no supergiant stars are found. In fact, long-exposure plates at the Mount Wilson Observatory have shown that the stars in these systems have a sharp upper limit on their brightness; no star greater than the critical brightness can be found, while below this critical brightness myriads of stars appear on the photographic plate. This result is in marked contrast to the observed brightness of the stars in spiral galaxies, where there are always one or two brightest supergiant stars, a number of less bright supergiants, and a gradually increasing number of fainter and fainter stars. This sharp upper limit on the brightness of stars in elliptical galaxies is just what one would expect if no new stars had been formed since the beginning of the universe, and if the brightest ones had burned up all their fuel and gone out.

Detailed examination of galaxies also indicates that clouds of matter between the stars are found only in spiral systems. In elliptical galaxies the vast stretches between the stars are very nearly empty, but in flattened spiral galaxies like our own there is about as much

matter between the stars as there is inside the stars. This association between obscuring clouds and supergiant stars is strengthened by the fact that in the closest galaxy, the great nebula in Andromeda, supergiant stars are observed to occur in exactly those regions where the obscuring clouds are most prominent. Thus the observational evidence indicating a physical connection between clouds and supergiant stars is very strong.

Before we can accept the hypothesis that supergiant stars have in fact formed from these clouds we must investigate whether or not there is some process which could cause interstellar matter to condense into stars. In this way we are led to consider the physical nature of the stuff between the stars, and the forces which operate on it. Thirty-five years ago the very existence of interstellar matter was not fully realized but recently extensive information on this topic has been obtained.

ATOMS IN SPACE

The dominant constituents of interstellar matter are believed to be individual atoms. These atoms absorb or emit light of particular wave lengths, which can be measured accurately by use of the spectroscope. In some regions, where the gas is at a high temperature, bright emission lines of hydrogen, oxygen, and nitrogen are observed. Measurements of the intensities of these lines show that the density of the interstellar gas is about one hydrogen atom in each cubic centimeter, with other elements present as slight impurities. The interstellar medium is a much better vacuum than is ever obtained in a terrestrial laboratory. If a fly were to breathe a single breath into a vacuum chamber as big as the Empire State Building, the resulting density of the air would still be much greater than the density of the interstellar gas.

In other regions of space the interstellar gas is cool, and no emission lines are produced. Instead, the atoms absorb the light from distant stars, producing absorption lines at particular wave lengths. The absorption lines of the abundant gases, hydrogen, helium, nitrogen, oxygen, etc., when these are cool, lie far out in the ultraviolet, where they cannot be detected. Interstellar absorption lines of sodium, calcium, titanium, and iron lie within the observable spectrum and have been observed in the spectra of bright stars a few thousand light-years away. These lines are very sharp, and can usually be distinguished from the lines produced by the atoms in a stellar atmosphere, where the high temperature and pressure give wide lines.

Recent work has been concerned with the detailed distribution of interstellar gas. Measurement of the strongest absorption lines, with the most powerful spectrographs available at the 100 inch telescope of

the Mount Wilson Observatory, shows that a single line is frequently made up of several components. Each separate component is produced by absorption in a single cloud of gas, the different components being separated in wave length by the difference in Doppler effect produced by the different cloud velocities. These clouds, each one about 20 light-years across, are moving through space at speeds of some 10 or 20 miles a second. A more detailed understanding of the nature of these clouds is desirable before one can discuss in detail how interstellar matter can form new stars. Further work along these lines is now in progress.

SOLID PARTICLES

In addition to the separate atoms drifting about in space, small solid particles, or grains, are also present. Each grain is about one hundred-thousandth of an inch in diameter; 10,000 placed end to end would make a line about as long as a period on this page. Since the size of these grains is just about equal to the wave length of visible light, these particles are of the size which is most effective in absorbing and scattering light waves. These particles are responsible for the general obscuration produced by the clouds shown in plate 2. Particles of smaller size are presumably also present, but these do not produce such a noticeable effect, and can therefore not be detected.

The properties of these particles have been determined from accurate measurements of the obscuration which they produce in light of different wave lengths. This obscuration is greater for blue light than for red light, which proves that the particles cannot be much *larger* in size than the wave length of light. On the other hand, the obscuration varies inversely only as the first power of the wave length, instead of as the fourth power which is observed for scattering by the molecules of the atmosphere. From this one can conclude that the grains are not very much *smaller* in size than the wave length of light. In this way a particle size of about the wave length of light has been determined. From the fact that the grains seem to scatter more than they absorb it seems likely that they are dielectric rather than metallic in composition. If, as seems likely, these grains were produced by the sticking together of individual atoms, the enormous abundance of hydrogen relative to other elements would be expected to produce solid hydrogen compounds, in particular, ordinary ice. However, impurities of all other elements would also be present.

Studies of the distribution of these grains have indicated that the clouds in which these grains are concentrated are apparently identical with the gaseous clouds already described. Thus whatever pushes atoms into clouds also pushes the grains together.

FORCES IN INTERSTELLAR SPACE

To discuss in detail how stuff in space can condense to form new stars we must determine the physical conditions of matter in space. In particular, we must combine the observational evidence described above with our knowledge of basic physical principles to investigate the different forces that are at work on the different particles. Only in this way can we predict how the interstellar medium will behave under various widely different conditions.

In the immense vacuum between the stars, an interstellar particle spends most of its time moving in a straight line without interruption. Occasionally, one of two things may happen to it: an encounter with another interstellar particle, or an encounter with a light wave, or photon. The information which physicists have obtained on such processes is not so complete as astronomers would like, but is sufficient for an approximate evaluation of the effects which these various collisions will produce.

The collisions of the interstellar atoms and grains with each other help determine the temperature of matter in space. In most cases, the collisions are elastic and the kinetic energy of the different particles is exchanged back and forth; as a result, the distribution of velocities corresponds to that in thermal equilibrium at some particular temperature. Photoemission of energetic electrons from hydrogen atoms and grains, on absorption of photons, tends to keep the temperature high, but inelastic collisions between atoms and grains tend to give a low temperature. Near a very hot and very bright star the gas will be heated up to about $10,000^{\circ}$ K., but in other regions a temperature of about 100° K. seems likely. This difference of temperature between different regions is believed to produce cosmic currents, or winds, in the same way as the winds on earth are produced.

In some cases the interstellar particles stick to each other on collision. Thus atoms stick together to form molecules, molecules stick together to form larger molecules, and grains grow by slow accretion. This process was analyzed during the war by a number of Dutch astronomers, who were able to show that the interstellar grains have probably been formed by this evolutionary process within the last few billion years. More accurate physical information on collisions between particles at low energies is required to make this theory more quantitative.

Collisions between grains and photons are important in star building. It is well known that light exerts pressure. Since starlight in a galaxy comes from all directions in the galactic plane, a single grain will be knocked this way or that by photon collisions, without any net motion resulting. However, when several grains are present, the shadow of each one on the other unbalances the radiative force, and

photons striking from the opposite sides push the grains toward each other. As a result, there is an effective force of attraction between grains which is several thousand times as great as the gravitational force between them.

STAR FORMATION

The farther we go away from observational data the more uncertain our theories become. The mechanism of star formation, which is the ultimate objective of much of the work described above, is still in a rather speculative state. However, putting all the above information together does provide a reasonable preliminary picture for the process by which stars can be formed from interstellar matter.

The process may be assumed to start with an interstellar gas, formed at the same time as the rest of the universe. The first step in the process is then the slow condensation of interstellar particles from the gas. After these particles have reached a certain size, the radiative attraction between them forces them together and they drift toward each other, forming an obscuring cloud in a time of about 10 million years. In a cloud, where the density of grains is high, the temperature tends to be low. In the surrounding region the high temperature produces high pressure, and the low-temperature, low-pressure cloud therefore becomes compressed. In this way the density of gas within a cloud will be increased, corresponding to the observed result that a cloud of grains is also a cloud of gas.

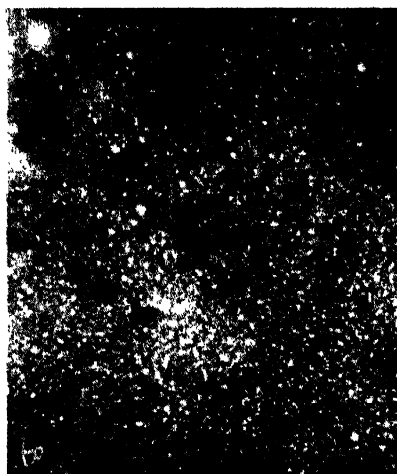
Currents produced by differences of temperature and also by the general rotation of the galaxy will tend to tear some of these clouds to pieces. On the other hand, the forces of condensation will pull them together and some clouds may be expected to go on contracting. The radiative force becomes ineffective when the clouds become so opaque that light does not penetrate into them very far. At this point gravitation takes over and tends to produce a further contraction. In this stage a cloud has a diameter of a light-year or less. Small opaque clouds of this type, called globules, have been known for some time, and are shown in plate 1, figure 1.

One of the chief problems concerns the angular momentum of this prestellar globule, or protostar. According to Newton's laws of motion, the angular momentum, which is proportional to the product of the radius and the rotational velocity, remains constant; as the radius decreases the rotational speed increases. Since the radius of a typical cloud is some 10 million times the radius of a supergiant star, this increase in rotational speed can be quite impressive. Unless some way can be found to dispose of the angular momentum, a protostar would hurl itself to pieces by centrifugal force. The possibility that turbulent motions in the gas may carry the angular momentum

away has been explored by several German astronomers. However, the turbulent velocities involved would exceed the velocity of sound in the interstellar gas, and physical information about this type of turbulence is virtually nonexistent. In this country the possibility has been advanced that a galactic magnetic field might produce electrical eddy currents in a rotating protostar, which would then damp out the angular momentum.

An interesting variant of this star-building picture has been proposed by Dr. Fred Whipple, one of the astronomers who has contributed most to this theory of star building. He suggests that a condensing cloud may have produced our solar system. In view of the widespread general interest in the formation of the solar system, such a bold extrapolation of these theoretical concepts back to conditions several billion years ago is naturally of much significance.

It is evident that the picture of star formation which has been described here is still in a formative stage. The work in progress is being carried out cooperatively by a number of astronomers all over the world. Perhaps when the 200-inch telescope probes further into the secrets of space, and when further progress in experimental and theoretical physics increases our understanding of the processes at work between the stars, we may then outline with more assurance the detailed steps by which supergiant stars may be forming almost before our very eyes.

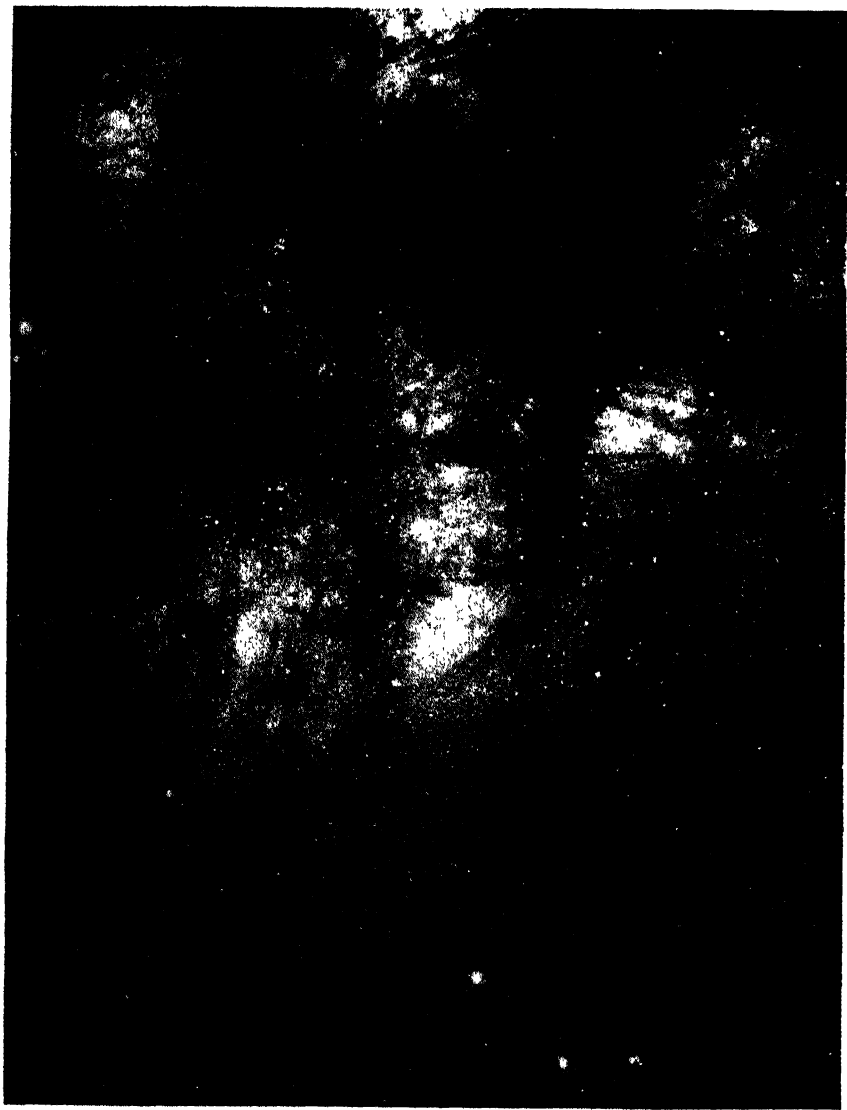


1. THE COMPACT OPAQUE GLOBULE MAY BE A PROTOSTAR, CONTRACTING TO FORM A NEW STAR



2. A TYPICAL SPIRAL GALAXY

Both supergiant stars and interstellar clouds of obscuring matter are found only in these huge, flattened, rotating systems. (Yerkes Observatory photograph.)



OBSCURING CLOUDS IN THE MILKY WAY ARE MANY LIGHT YEARS ACROSS, AND
ARE COMPOSED OF ATOMS AND TINY SOLID PARTICLES

(Yerkes Observatory photograph.)

THE ORIGIN OF THE EARTH

BY THORNTON PAGE
Yerkes Observatory

[With 11 plates]

With all the spectacular success of recent scientific research, it is perhaps refreshing to examine a field so characterized by failure as this one. Although many speculations have been described as "theories," there exists today no real theory of the origin of the earth in the sense of a complete logical structure linking together the vast quantity of pertinent observations collected during the last century.

The most obvious approach to the problem is to study the visible surface of the earth for clues to its origin. This has been done in detail by geologists, geodesists, geophysicists, and geochemists, but it is perhaps not surprising that what they find has more to do with the earth than with its origin. It has been the astronomer, studying the relation of the earth to its surroundings, and the physicist, studying the behavior of matter, who have made the greatest progress in the study of the earth's origin.

Early speculation on the subject was simple and direct because there were fewer observations to explain. The assumption of a divine creation of things as they are was generally accepted until the end of the sixteenth century. Then the revolution in scientific thinking, started by Galileo, turned men from assumptions of a catastrophic origin to a belief in natural development, understandable in terms of what can be seen and measured today. As the astronomical picture became clearer, it appeared that the earth is a relatively small, nearly spherical body moving around the sun together with the other planets, all under the influence of the sun's gravitational attraction. It was soon recognized as scarcely due to chance that all the known planets and their satellites are moving and rotating in the same direction, their orbits nearly circular, and in nearly the same plane. Therefore, in 1755, the great German philosopher-scientist, Immanuel Kant, speculated that the planets and the sun were formed from a single large rotating gaseous cloud, or nebula, which had condensed into smaller rotating parts, these further condensing into rotating planets with

¹ Reprinted by permission from *Physics Today*, vol I, No. 6, October 1948.

their satellites, all moving in the same direction round the nucleus of the nebula which became the sun. Kant's hypothesis explained nearly all of the available observational data within the framework of physics as it was developed at the time.

Later on, about 1800, the French mathematician, Laplace, independently proposed a modified form of the Kant hypothesis which, even though it was not given much weight by its author, soon became widely accepted as the concept upon which much of geology was founded. Laplace went further than Kant in explaining how the primordial nebula condensed into planets. He assumed that in the beginning the nebula was hot and spinning slowly, that the gas contracted as it cooled and therefore increased its spin in accordance with the law of conservation of angular momentum. As the spin increased, he reasoned, rings of gas would be thrown off by centrifugal action and each ring would condense into a planet. It is now recognized that no such condensation of hot gas at the rim of a spinning nebula would take place, but Laplace's speculation was important in that he introduced two new factors: the idea that the earth condensed from hot gases, and the consideration of angular momentum in the solar system.

Not until 1895 was the Laplace hypothesis seriously challenged. By that date geology had come into its own as a science, and T. C. Chamberlin, an American geologist, considered the geological evidence incompatible with the concept of a hot gaseous sphere cooling to become the present earth. Instead, he proposed the planetesimal hypothesis, in which the earth and other planets were built by accretion of cold particles (the planetesimals) which were moving around the sun under its gravitational attraction. Together with an astronomer, F. R. Moulton, he suggested that such planetesimals might have resulted from a near-collision between another star and our sun. The planetesimal hypothesis introduced two new concepts: that the earth was built by accretion of cold solid material, and that another star was involved in forming the solar system. The near-collision presumably being a rare event, this represented a return, in part, to the old concept of a catastrophic origin.

During the last 50 years, most of the thinking on this problem has been divided between the two widely divergent hypotheses of Laplace and Chamberlin. Did the earth start hotter or colder than at present? Has it condensed and contracted, or grown by accretion? Was its origin a commonplace occurrence in a nebula (many of which can be seen in the sky), or due to a highly unusual near-collision between stars? Whatever drawbacks these incomplete speculations may have had, they have provided definite concepts on the basis of which further research has been and yet remains to be done.

THE RECORD IN THE ROCKS

In geology it is assumed that we can explain past developments on the basis of processes taking place today, and this assumption has been remarkably successful in tracing geological history to form a consistent pattern. The surface features of the earth can be explained as the expected result of erosion, of glacier action, of volcanism, and of movements of the crust itself, all of which are observed in action now. This reasoning might be expected to lead, step by step, to the origin of the earth.

The sequence of events in earth history is best summarized by the geologic column, a schematic pile of all the rock strata which have been classified, in the order of their formation. After fitting together rocks from all over the world, there are left only four major gaps in the record, when erosion in practically all parts of the earth now above sea level must have eliminated the rock deposits of millions of years. With these four exceptions, the geologic column, fitted together from the results of a century of world-wide geologic prospecting, gives almost as complete and consistent a picture of earth history as if the entries had been made in a diary. It lacks only the number of years intervening between the various geologic eras.

The dates were supplied when the absolute ages of rocks were estimated from their radioactivity, first in 1905 by Boltwood, an American physicist. He measured the relative amounts of lead and helium in uranium deposits. The uranium ore crystallized when the molten magma solidified, and the radioactive uranium has since been disintegrating at a constant but very slow rate to form lead and helium which, in favorable cases, have both remained sealed in the igneous rock with the uranium. The process of radioactive decay has been thoroughly studied in the laboratory by many physicists, including the Curies and Rutherford (who suggested Boltwood's research), and the rate of disintegration accurately measured.

Dating various igneous rocks in the geologic column showed first how very long was the record; the oldest igneous rocks yet dated crystallized about 3 billion years ago. Moreover, there are even older sedimentary rocks through which the molten magma had pushed to form these oldest known igneous rocks; hence the earth must have had surface conditions about 3 billion years ago not radically different from those today. There must have been water and an atmosphere operating to erode rocks and form sand and mud beds. Fossils in somewhat younger rocks indicate that early forms of life existed at least 1 billion years ago when conditions must have been very like those today.

But the geologic column fails to yield the one feature which might provide conclusive evidence on the earth's origin. No rocks yet examined have the appearance of an original crust; they are all either old sediments or solidified magma which pushed up through sediments.

TEMPERATURE AS A CLUE

Trying another tack, we might expect that the earth's thermal history could be traced back to determine its temperature at birth. In deep mines and wells the temperature increases 1° C. for each 125 feet below the surface. Knowing how rocks conduct heat, we find that 10 million million calories of heat are flowing out from the earth's interior each second. If the earth were solid granite, all 7,000 billion

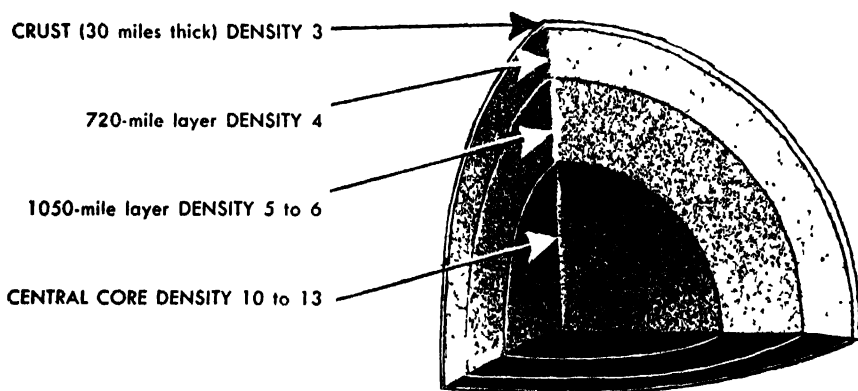


FIGURE 1.—Density stratification in the earth. Seismologists, using earthquake waves as a sounding device, have discovered these layers within the earth. They may indicate that the earth was once molten; or they may result from chemical compaction and plastic flow within the earth.

billion tons of it, this escaping heat, would cool it about 1° C. in 3 million years. From this measured rate of cooling is it possible to determine whether the earth was originally molten?

One must be careful in such estimates; not all of this heat comes from cooling the earth, since the radioactive disintegration so useful in determining the age of rocks is also releasing energy. In fact if the measured radioactivity is constant with depth, the outer crust of the earth only 12 miles thick would provide all the 10 million million calories leaving the earth's interior. If the radioactive material goes deeper than 12 miles, the earth must, willy-nilly, be heating up! So the heat now leaving the earth does not give a clue to its original temperature, although it does point to another approach. Since it is improbable that the earth is heating up rapidly, the radioactive material probably is not distributed uniformly throughout the earth but is concentrated in surface layers.

Such a stratification within the earth might have a bearing on the original conditions. For instance, if the earth were once molten, we might expect heavier materials to sink to the center and lighter ones to come to the surface. A variety of measurements do prove that the earth is much more dense at the core than at the surface, and this central condensation was long used to support the concept of an originally molten globe. In fact, the central core itself was generally believed still to be molten. But a few years ago, observations of faint earthquake waves which could only have passed through the core if it were solid, disputed the point.

It is now generally accepted that the earth's interior is stratified in three distinct layers on a central core which is four times as dense as the surface rocks, and although probably as solid throughout as surface rocks, it yields to plastic flow over long intervals of time. (The molten lava of volcanoes is only in local pools liquefied by a temporary release of pressure.) Recent work by geochemists shows that at least some of the stratification is due to chemical compaction, the tremendous pressures favoring the formation of heavier chemical compounds in the interior. There is no satisfactory explanation of the dense core, which must be a material radically different from surface rock. But its existence can no longer be used with certainty to argue that the earth was once molten.

CHEMICAL CLUES

Geochemical studies give a somewhat better clue to the earth's temperature at birth. Harrison Brown at Chicago has recently shown that all the elements which exist mainly in gaseous form—hydrogen, helium, neon, argon, krypton, xenon—occur in the earth, its seas and atmosphere, to a very much smaller extent than expected from studies of the abundances of elements, both from theory and from observations of the sun and stars.

The low abundance of hydrogen and helium is easy to understand: at temperatures of 500 to 600 degrees Centigrade they would escape from the gravitational attraction of the earth in a few hundred million years because of the high velocities and small masses of their molecules. But the heavier atoms, krypton and xenon, could have escaped in quantity only if the material of the earth were at one time in much smaller pieces, with correspondingly smaller gravitational attraction, or if the earth had for some time a temperature of 10,000 to 30,000° C. Now this is hotter than most stars, and quite impossible for the earth to maintain, so we deduce that early in its history the material of the earth was in separate, small pieces. Since oxygen, nitrogen, and water-vapor molecules are all lighter than krypton (and would therefore escape if krypton did), it appears that the earth's atmosphere and

oceans must have been formed from the decomposition of heavier compounds after the earth achieved its present size.

To summarize the best geological evidence: the earth is at least 3 billion years old and its surface conditions of temperature and atmosphere have not changed materially in 1 billion years and not radically in 3 billion years. Its stratified layers from density about 3 at the surface to density about 13 at the center could result from plastic flow and chemical compaction whether or not the earth were originally molten. Finally, the earth lost most of its gases early in life, probably because it was at one time in pieces of too small mass to hold on to light gas molecules.

SHOOTING STARS

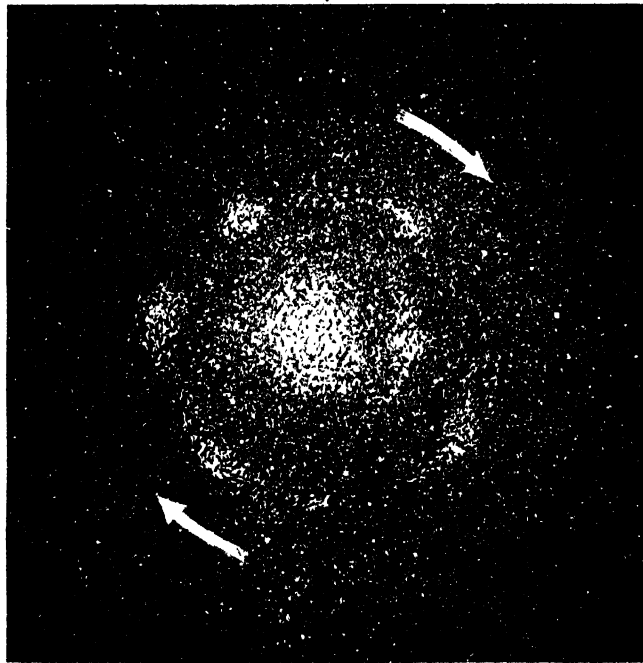
An important bridge between geology and astronomy is provided by the meteors. Millions of these small chunks of rock and iron collide with the earth each day, most of them burning up high in the atmosphere. Some of the larger, slower-moving ones reach the ground; there the few collected are the only material from outside the earth available for detailed study. Are they a few remaining planetesimals—or are they visitors from outside the solar system?

Measures of meteor speeds by Whipple at Harvard have established that they are at least members of the solar system. If they came from outside they would be moving much faster than observed. Radioactivity measurements (as in dating rocks, but corrected for the effects of cosmic rays which form extra helium) show that the meteors are between 2 and 3 billion years old, in startling agreement with the earth's age. Their high iron and nickel content has supported the assumption that the earth's core is nickel-iron (so that earth and meteors would have the same over-all composition).

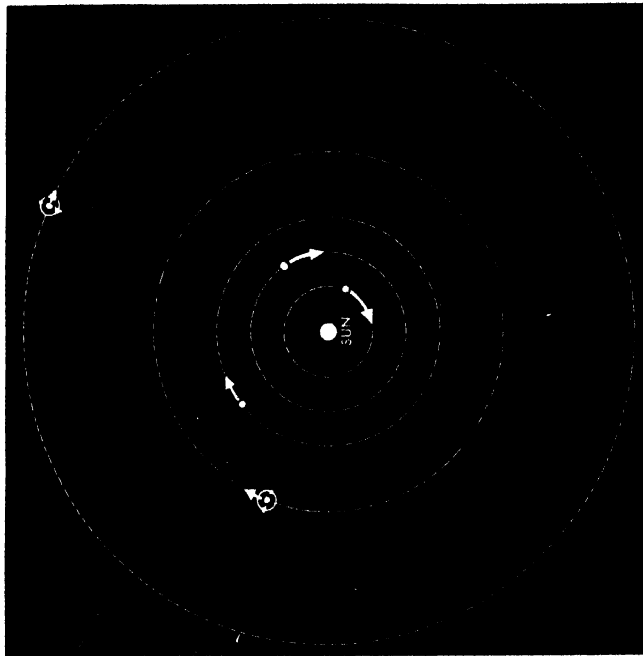
Furthermore, Harrison Brown's recent studies of the chemical compounds present in meteorites show that they were probably at one time under the high pressures and temperatures of a planet's interior. It would seem that, far from being planetesimals, the meteors are the remains of a fair-sized planet which was formed at the same time as the earth, and which broke up in some large-scale interplanetary collision at a later date.

THE GAMUT OF SPECULATION

The astronomer, in his approach to the problem of the earth's origin, started by recognizing a certain order and regularity among the planets, their satellites, and the smaller asteroids, all moving about the sun. The emphasis is shifted from the origin of the earth, as one of the planets, to the origin of the solar system as a whole. The latest trend goes even further in linking the origin of the solar system with

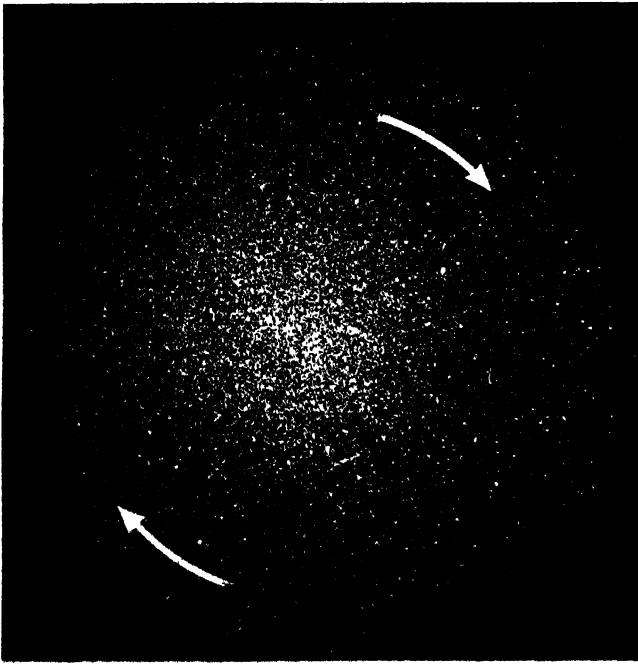


1. Clotting mass of gas and dust in rotation.



KANT-1755

2. Clots grow by accretion to form planets and satellites. Remainder of nebula contracts to form sun.

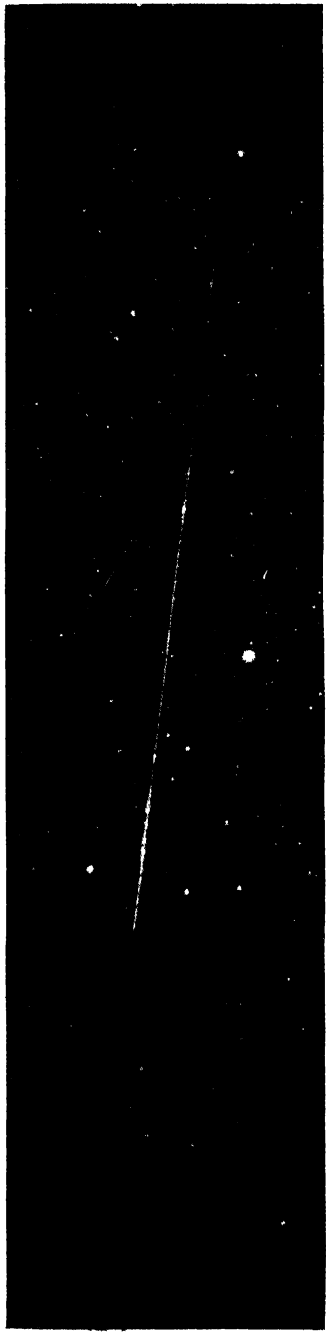


1. Rotating nebula of hot gas.



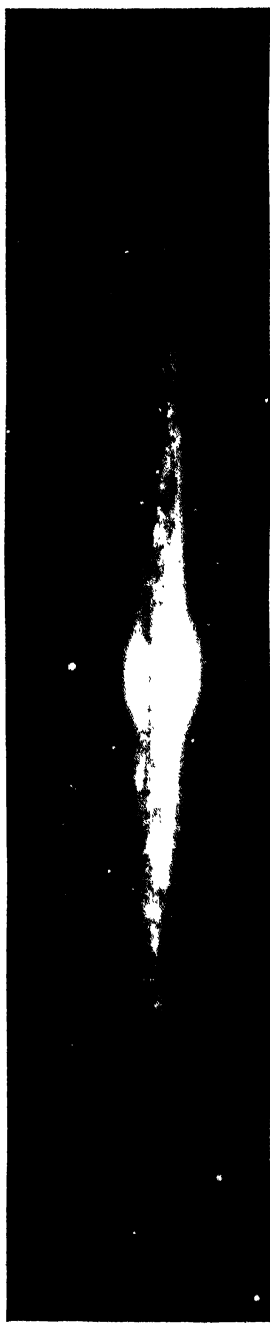
2. Cooling nebula shrinks, spins faster, and is expected to leave rings of gas to condense into planets. The remainder forms sun.

LAPLACE—1796



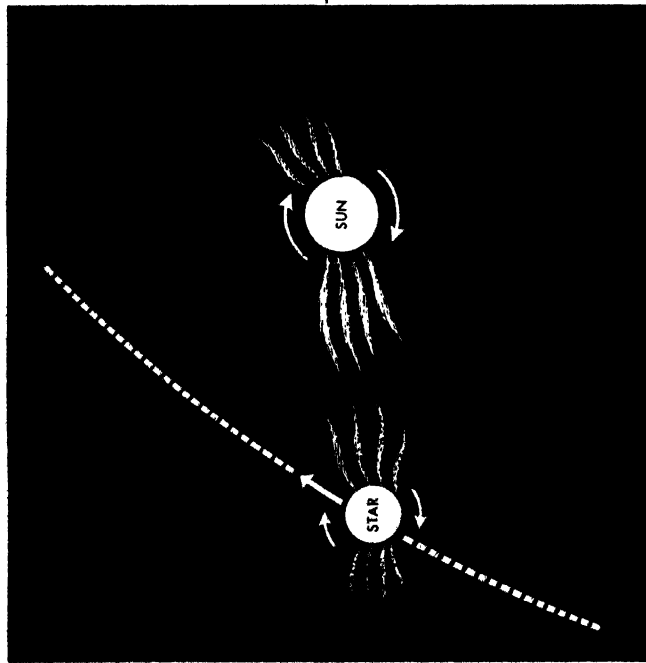
1 PHOTOGRAPH OF A METEOR TRAIL

As the meteor flashed across the sky a spinning blade in front of the camera lens interrupted the exposure every $\frac{1}{10}$ second. From the length of the dashes the speed of the meteor can be determined. (Photograph by Whipple, courtesy Harvard College Observatory)

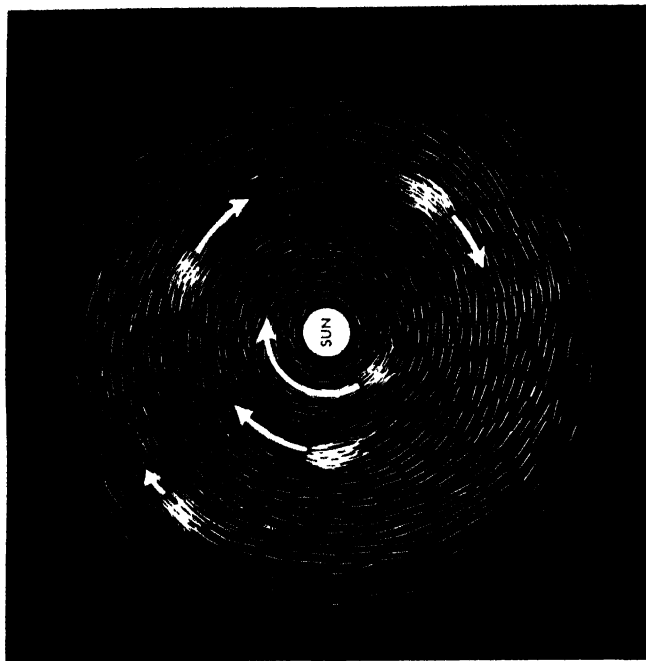


2. SPIRAL NEBULA. EDGE VIEW

(Photograph of NGC 4565, courtesy Mount Wilson Observatory.)

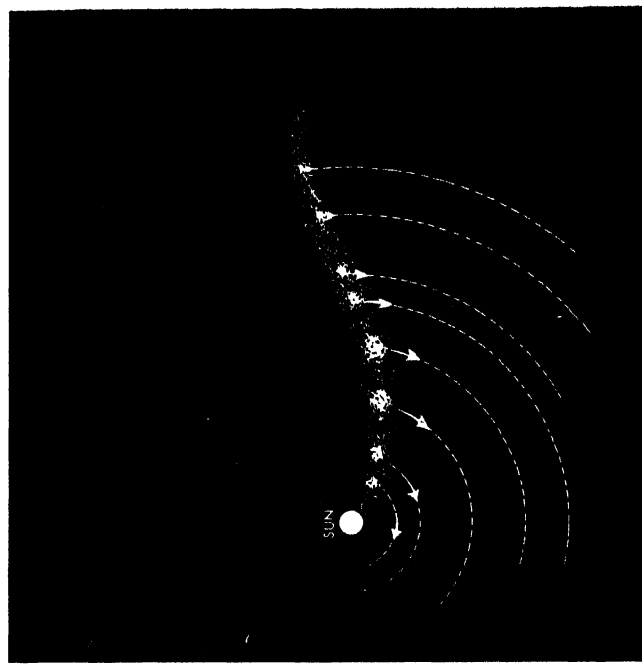
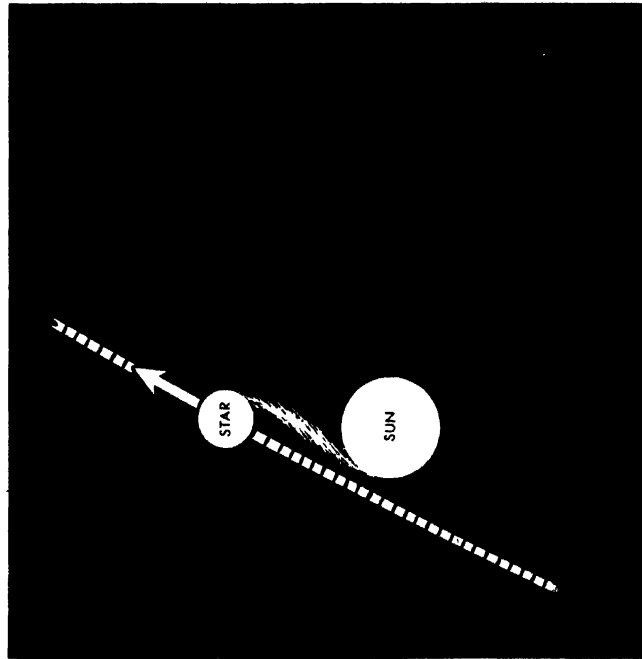


1. A passing star narrowly misses the sun. Huge eruptions were expected to occur on both as they pass.



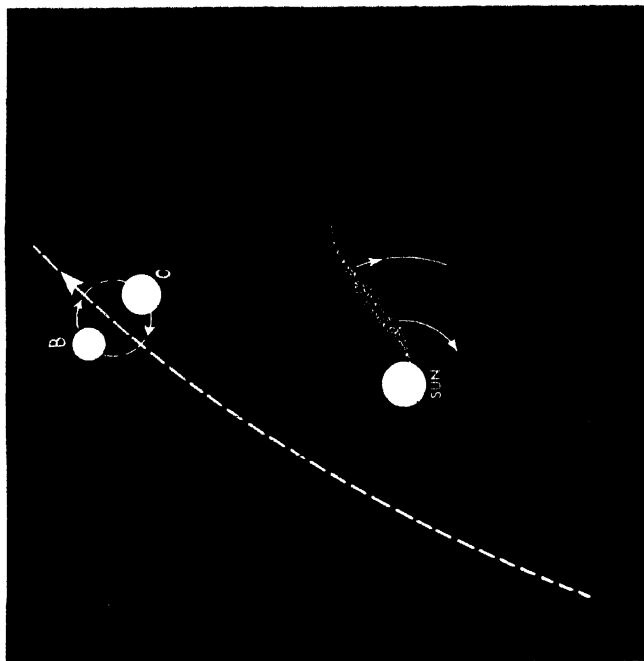
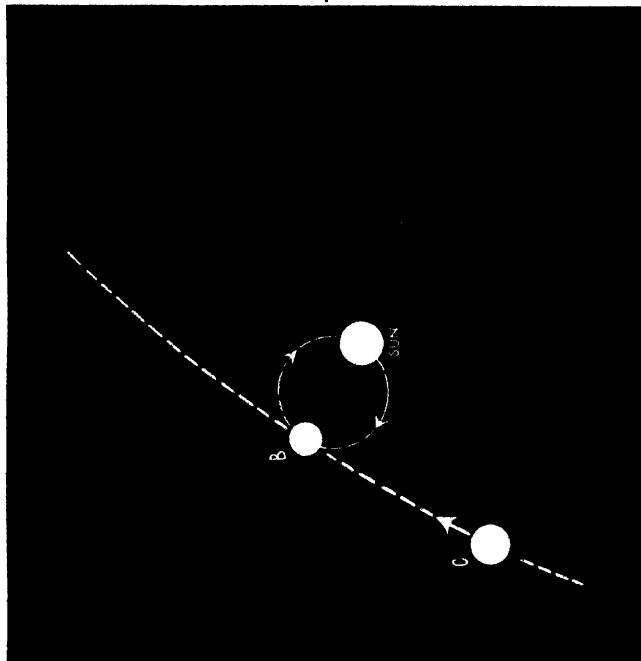
CHAMBERLIN-MOULTON—1900

2. The sun is left with a vast number of planetesimals which condensed from the erupted gases and slowly coagulate to form planets. The intruding star should also have planets forming.



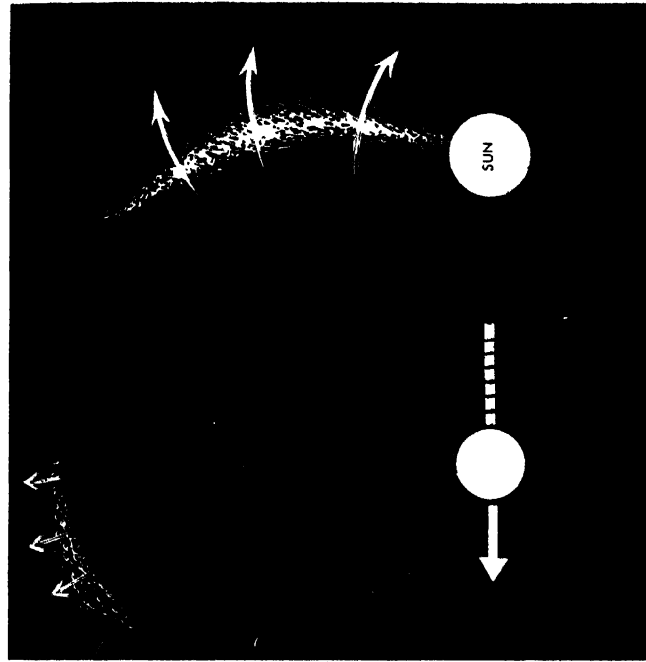
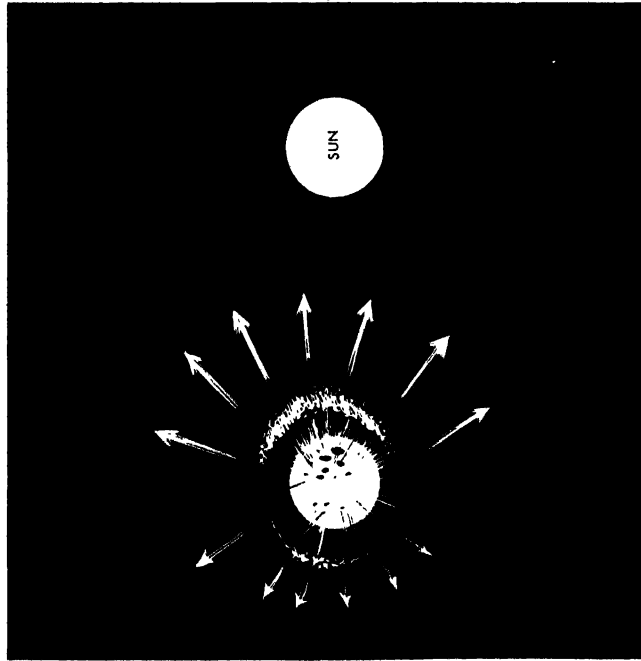
JEANS-JEFFREYS—1917

1. A passing star sideswipes the sun, tearing out a long filament of gaseous material.
2. The gas was expected to cool and condense into planets, the largest one in the middle and the smaller ones at either end.



LYTTLETON—1936

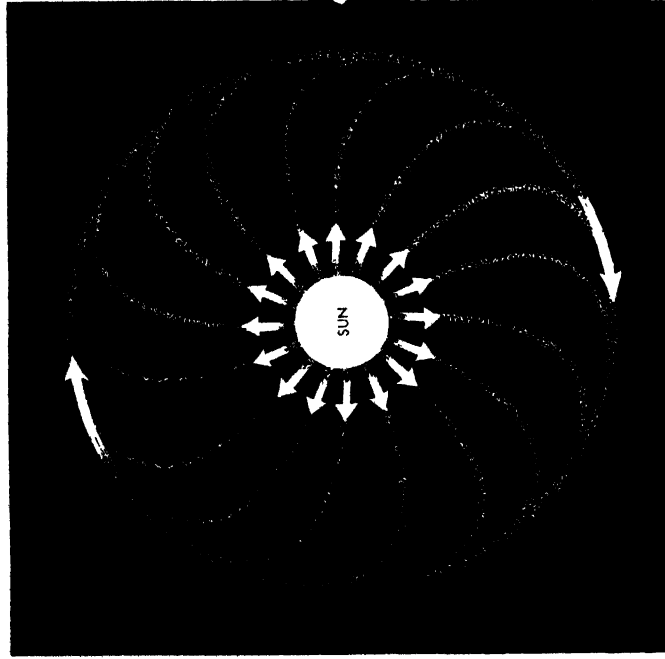
1. If the sun originally had a close companion, B, spinning around it, a third star, C, might have sideswiped the companion. . . .
2. . . . carrying it away, and leaving a filament of its gas moving around the sun, with lots of angular momentum.



HOYLE—1944

1. A star near the sun might have blown up, throwing off a large shell of material, possibly more in one direction than the others. Such nova explosions are observed frequently.

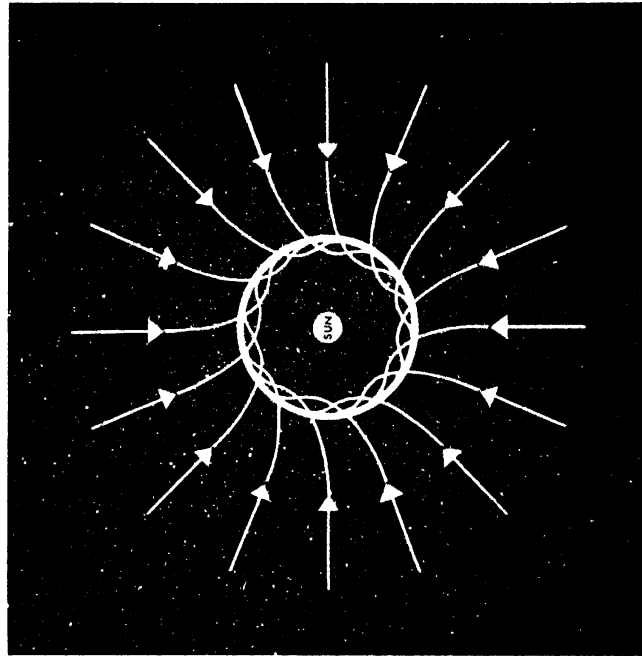
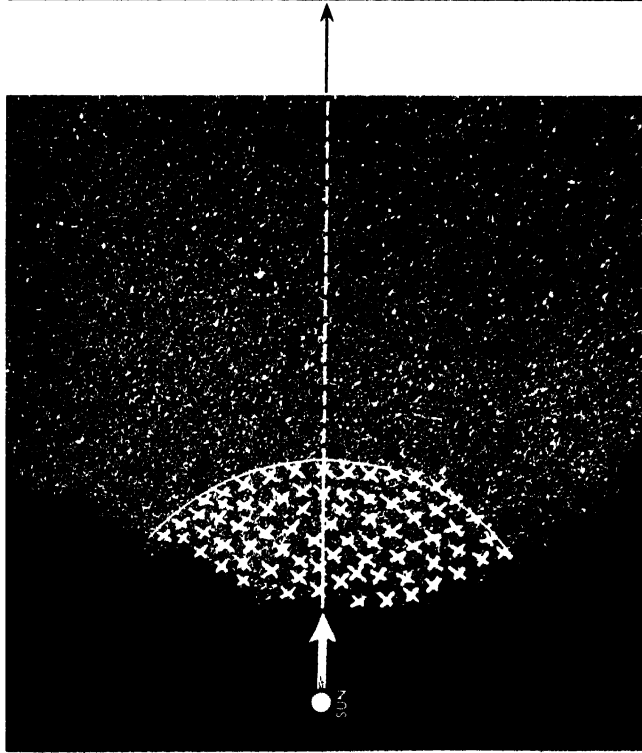
2. Part of the nova shell could be caught by the sun's gravitation, while the nova itself recoiled away from the one-sided explosion.



BERLAGE—1930

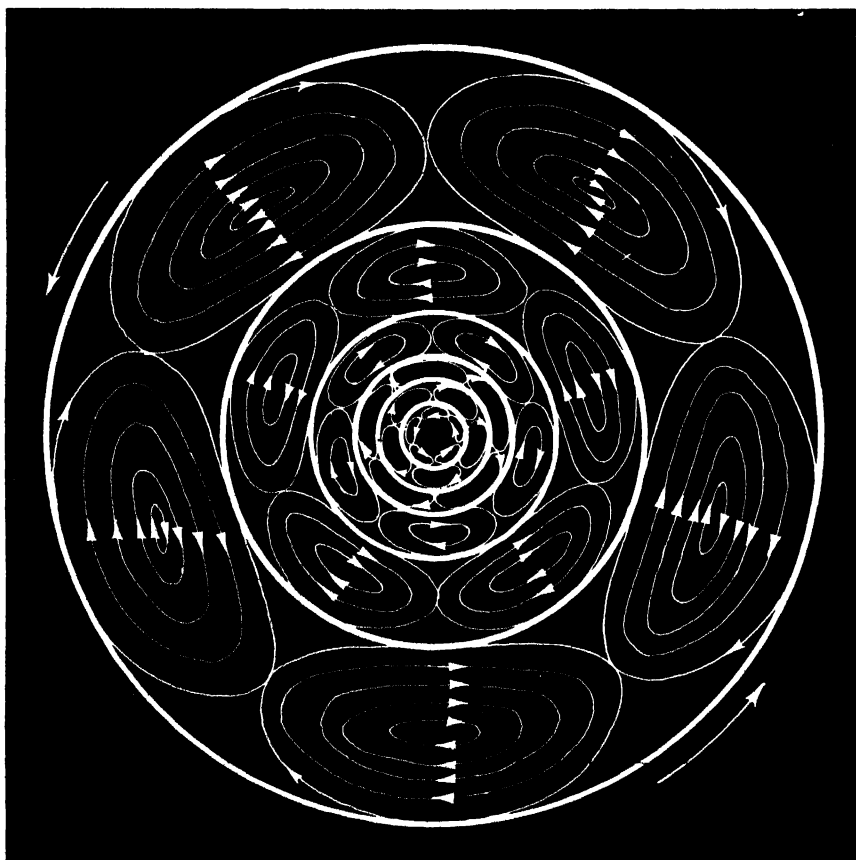
1. Electrically charged atoms and molecules shot out of the sun spiral in the solar magnetic field.

2. Rings of gas result, each ring formed of atoms or molecules with the same ratio of charge to mass. Condensation into planets is uncertain.



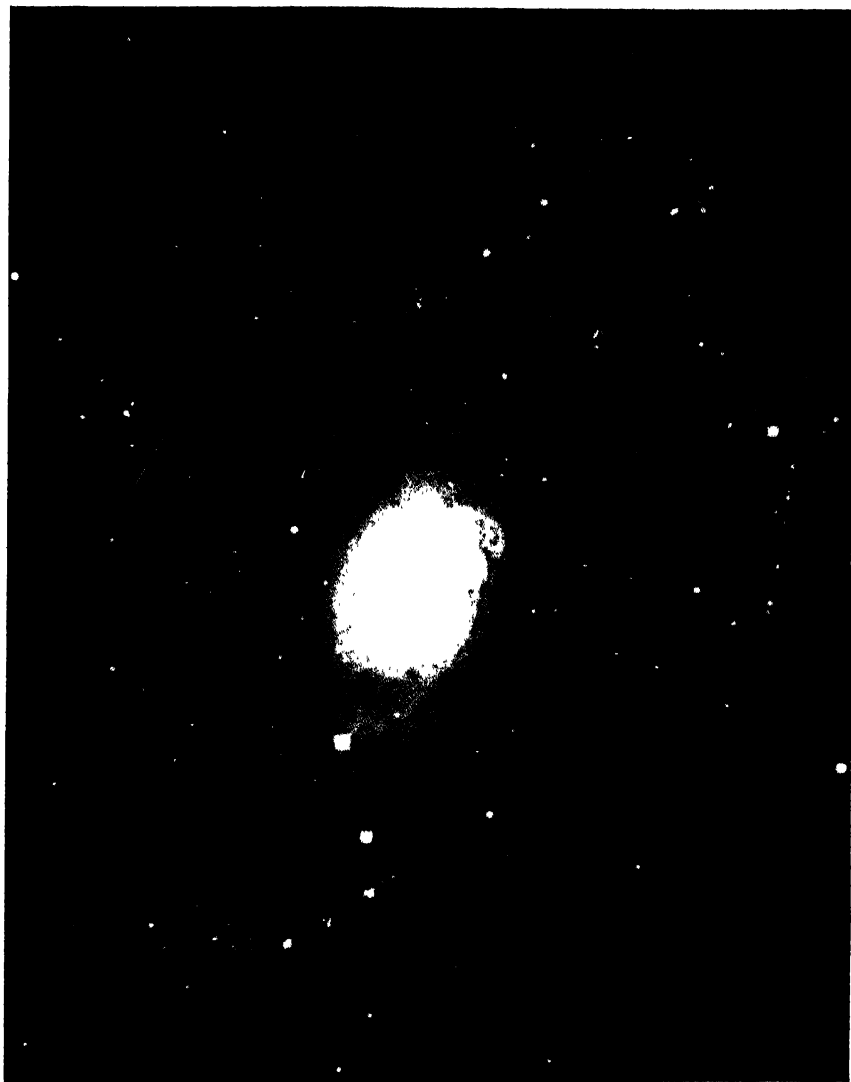
ALFVÉN—1942

1. The sun, rushing through space at 12 miles per second, passes through a gaseous nebula. Its presence creates electric charges on the atoms of gas.
2. The charged atoms spiral inward to form rings of gas (only one is shown here) which might later condense into planets.



WEIZSACKER—1945

Vortices formed in the equatorial plane of a nebula of gas and dust rotating about the sun, according to Weizsäcker. Accretion is expected to take place along the heavy concentric circles to form planets and satellite systems with direct rotation and revolution.



MESSIER 81

A great spiral nebula in the constellation Ursa Major, about 2 million light-years away and 200 million times as bright (intrinsically) as the sun.

the early history or origin of our galaxy of stars and even of the whole universe.

The solar system regularities noted by Kant clearly indicate that the planets had a common origin; ever since Kant's time it has been the fond hope of cosmogonists to establish the exact nature of that origin from further studies of the over-all pattern of the solar system. The first clue of this sort to be noted was the spacing of the planets; they are not at irregular distances from the sun, but spaced approximately in geometric progression—that is, the distances can be calculated roughly from a formula called Bode's law after its discoverer. Since the planets continue to move in the same orbits year after year, this spacing must have been established during their formation.

A second possible clue to the origin lies in the progression of planet sizes—from the smallest, Mercury, which is nearest the sun, increasing through Venus, Earth, and Mars to Jupiter, the largest, then decreasing through Saturn, Uranus, and Neptune to Pluto, a small planet, and most distant from the sun.

Further clues will be noted as we follow, now, the twentieth-century history of speculation on the birth of the solar system, from Chamberlin to Weizsäcker and Whipple. Each of these theoreticians has started either from the Kant nebular hypothesis, or from the Chamberlin two-star hypothesis, and tried to show by more or less exact reasoning that the presently observed solar system would have resulted naturally. Chamberlin and Moulton in 1900 guessed that the close approach of another star to our sun would raise great eruptions on the sun, that hot solar material would con-

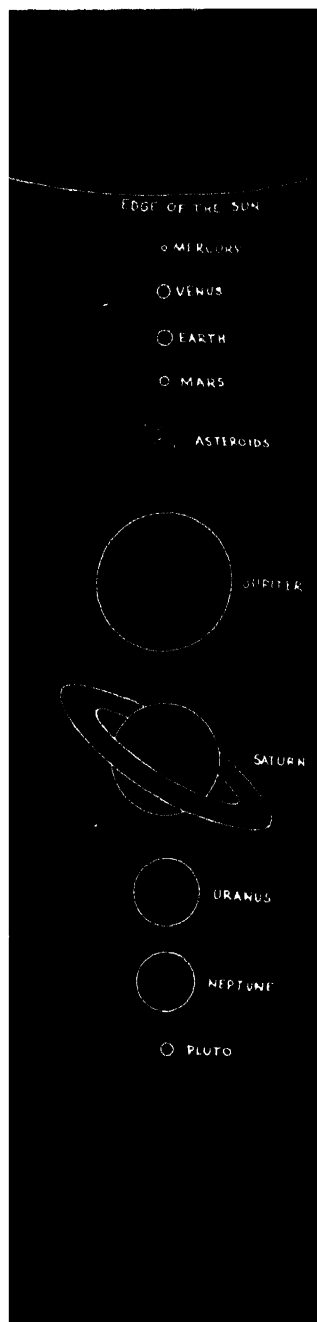


FIGURE 2.—Scale of planet sizes.

dense into small planetesimals moving around the sun and that these planetesimals would later stick together to form the planets by accretion.

In 1917 the English astronomers Jeans and Jeffreys made more exact calculations and concluded that the eruptions would not have taken place; rather, the intruding star would have to sidewipe the sun, peeling off a long filament of solar material which would then condense into the planets. They pointed out that this filament would be thicker in the middle than at the ends, thereby accounting for the progression of planetary sizes.

The Jeans-Jeffreys hypothesis seemed satisfactory until 1930, when Nölke in Germany and Russell at Princeton pointed out another clue: the angular momentum of the planets. Just as a spinning top would keep on spinning forever if there were no friction, so the planets must have maintained constant angular momentum in their orbits around the sun, since nothing analogous to friction is known in the solar system. If the planets were formed from material pulled out of the sun, this law of conservation of angular momentum requires that the original planetary material must have started moving around the sun with the same angular momentum the planets have today. Russell showed mathematically that a grazing collision with another star could not start the filament of planetary material off with anywhere near enough angular momentum.

In an effort to patch things up, one of Russell's students, Lyttleton, analyzed mathematically the case of a collision between three stars, and found that it was just possible to produce a filament of material moving with sufficient angular momentum about one of them. An English astronomer, Hoyle, showed it was also possible if one of two close stars blew up, as a somewhat asymmetrical nova, propelling itself away and leaving some planetary material moving around the other star.

But these mathematical exercises and the whole sequence of speculations based on the two-star hypothesis were brought sharply to a close in 1939 when Spitzer, another of Russell's students, calculated that the material pulled out of the sun, or any other star, could not condense into planets or planetesimals anyway—it would expand with explosive violence to form a tenuous gaseous nebula!

BACK TO THE NEBULAR HYPOTHESIS

Long before Spitzer had showed that the two-star hypothesis would lead to a nebula, other scientists had been working away on the nebular hypothesis, trying to find some means by which material near the sun would form a group of planets all moving in the same direction in nearly circular orbits and in nearly the same plane. In

1914 a Norwegian physicist, Birkeland, calculated that electrically charged particles shot out of the sun would spiral out in the sun's magnetic field to definite circular orbits at distances depending on the ratio between the electric charge and the mass of the particles. This promising lead was followed further in 1930 by a Dutch meteorologist, Berlage, who assumed the particles were charged atoms. More recently, in 1942, the Swedish physicist, Alfvén, was able to predict by similar reasoning that rings of gas with sufficient angular momentum would be formed around the sun as the sun moved through a nebula, but both he and Berlage have avoided the embarrassing problem of how this gas could condense to form planets.

Lastly in the sequence of nebular speculations, a German physicist, Weizsäcker, has recently investigated in detail the motion of a large cloud of dust and gas in rotation about a massive central body like the sun. From this return to the ungarnished Kant hypothesis he was able to show that, while most of the gas would escape into outer space, the planets could be formed by the accretion of the dust particles over a period of a hundred million years—a short time compared to the age of the earth. The spacing of the planetary orbits Weizsäcker explains in this manner: The inner parts of the rotating nebula would be pulled around more rapidly by the sun's gravitational attraction than the outer parts. Like stirring a bowl of soup near the center, this would set up eddies, and at the boundaries of the eddies the dust would coagulate most rapidly. These boundaries, Weizsäcker calculated, would be spaced approximately in a geometric progression from the sun just as the planets are observed to be.

The Weizsäcker hypothesis accounts for more of the observational data than any of the previous speculations, but because it is so recent a number of its consequences have not been explored and some of the estimates may need revision.

One of the interesting consequences is that the formation of planets should be an extremely common occurrence. Possibly in the process of formation of *every* star the conditions would be correct to form planets. Thus we might expect billions, if not hundreds of billions of planets in our galaxy, the strong likelihood that life has developed on a million or more of these, the high probability that there are other civilizations of mankind, and even the possibility that men on other planets are writing articles on the origins of their solar systems!

THE ORIGIN OF STARS

But where did the original gas and dust come from? How was it started in rotation? One reason the Weizsäcker hypothesis has received so much attention is that a separate line of research on the origin of the stars has provided answers to these questions. The argument hinges on the energy necessary to keep the stars shining.

The closest star—our sun—is radiating energy at such a stupendous rate that no ordinary energy generator could keep it going for the 3 billion years we know it has been shining on the earth. However, it is now known that atomic energy provides the sun's light and heat by a process in which four atoms of hydrogen are converted into one atom of helium and the excess mass changed into radiant energy. The details of this process, which can only proceed at the high temperature and pressure of a star's interior, were established by Hans Bethe at Cornell in 1938. But there are many hot stars thousands of times brighter than the sun (if viewed from the same distance), and a simple calculation shows that they would use up all their atomic energy in a mere 10 million years. Where did these hot bright stars come from if they can last only one three-hundredth as long as the earth has been in existence?

A possible answer was provided only last year (1947) by Lyman Spitzer at Yale, and Bart Bok at Harvard. Spitzer showed theoretically that diffuse gas and dust which is observed between the stars could, under some circumstances, be compressed by the pressure of radiation from all the other stars, to condense into a new star. Bok observed in the Milky Way certain small dark knots of such interstellar material, which may well be stars in the process of formation. Here is the process of growth by accretion on a much larger scale. This theory is well enough established that Whipple at Harvard has recently proposed that the planets coagulated in the manner postulated by Kant and by Weizsäcker during the formation of the sun itself.

GALAXIES

As we are pushed farther and farther in explaining the origin of our planet, new sources of evidence come into the problem. The next evidence comes from a study of the large groups of stars called galaxies.

Passing from the solar system to the stars is no larger a jump—and no smaller—than from the earth to the solar system. Our galaxy includes all the visible stars and is a correspondingly large system, outside of which the telescope shows many other galaxies. These are believed to be very like our own galaxy—a disk-shaped conglomeration with a mass, determined from its rotation, of about 200 billion star masses. There are about 100 billion stars in a galaxy, the rest of the material being spread between the stars in the form of gas and dust.

The outside galaxies, often called "spiral nebulae," are being studied by Hubble at the Mount Wilson Observatory in California, and by other astronomers with large telescopes. As Hubble looks farther and farther out into space (by taking longer photographic exposures with larger and larger telescopes), he finds more and more

spiral nebulae, apparently without limit. In 1925 Hubble and Humason found from the redness of their light that the more distant spirals are receding from us more rapidly than the closer ones, and that the speed of their retreat is in direct proportion to their distance from us. At first sight this appears to leave our galaxy (with our sun and earth) in a central and somewhat unpopular position, with the rest of the universe running away. But a little thought shows that our view of the universe is the same as the view from any one of the other galaxies; each would see the rest receding from him with velocities proportional to their distances from him.

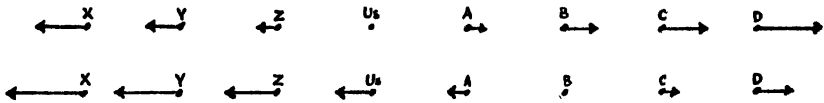


FIGURE 3.—Upper, our view of some spiral nebulae. The arrows indicate velocities. Note that spiral *B*, which is twice as far from us as spiral *A*, is receding twice as fast. *C*, three times as far, is receding three times as fast, and so on. Lower, the view of an observer on spiral *B*, considering himself to be at rest. It is the principle of relativity that he has just as much right as we do to consider himself at rest. He gets the same view as we do; all the spirals are receding from *B* with velocity proportional to distance.

Tracing the motions back in time (there is no evidence that the spirals are accelerating or decelerating) shows that all the spiral nebulae would have been near our galaxy between 2 and 3 billion years ago. The coincidence of this with the age of the earth and the age of the meteorites is too marked to need further comment—the whole universe seems to have started with a bang about 3 billion years ago!

THE BEGINNING OF TIME

This curious evidence that the spiral nebulae were all close to—if not entangled with—our galaxy 3 billion years ago, means that the formation of the solar system at that time probably took place under conditions somewhat different from those of today. To be sure of the reasoning, we must examine the conditions of 3 billion years ago more carefully; it was this reexamination which led, in 1945, to the most bizarre suggestion of all in this field already rich in speculation. It was put forward by the English biologist, J. B. S. Haldane, and is based on a new theory—or philosophy—of relativity proposed in 1932 by the English mathematician, E. A. Milne. First we shall speak of Milne and his brand of relativity.

To make the reasoning clear we must start with Einstein's earlier relativity theory which links space and time in such a way that if one observer is moving at constant velocity past another his measurements of distances and time intervals will differ from those

of the first observer, although the relation of time and distance is such that they both observe the same laws of physics. Einstein formulated his relativity on the philosophy that it is simply impossible to tell which observer is "at rest." Complicated as it sounds, this scheme has been developed to form a logically complete theory in terms of mathematical transformations. Milne extended the established principles of relativity in his "cosmological principle," which is, in effect, an assumption that the view of the whole universe from one spiral nebula must be the same as the view from any other. Moreover, he has redefined distance measurements in terms of the travel time of light signals, as in radar ranging, thus reducing both time and distance measurements to readings of clocks, in principle.

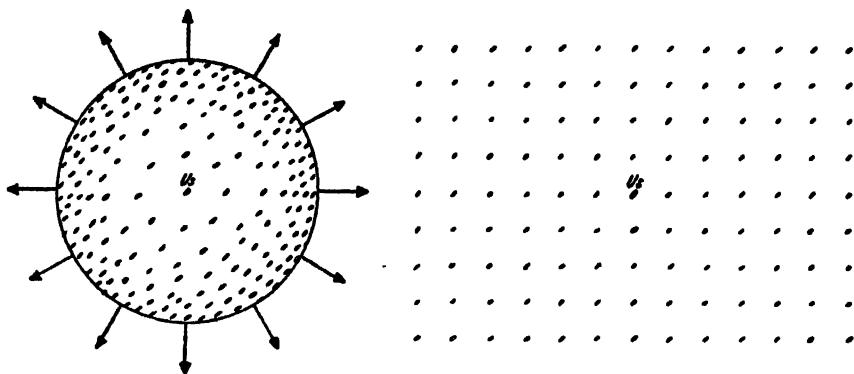


FIGURE 4.—Milne's picture of the universe. If all measurements are made in atomic time, on Milne's theory, the universe started expanding from a point 3 billion atomic years ago. As we see it now the spiral nebulae shown in the left diagram are all moving away from us and (if we could see far enough) would be much more numerous near the "edge." At this edge the velocity of recession is equal to the velocity of light, so we can never hope to see the edge itself. On the other hand, if clock time is used for all our measurements, the universe is static and the spiral nebulae, as shown on the right above, are uniformly distributed on to infinity. The more distant nebulae are redder because we see them as they were many years ago with "slow" atoms. The "edge" of this picture comes when this reddening gets so extreme that galaxies are no longer visible.

Milne then raises the disturbing question: How are we sure that our clocks are reading constant intervals of time? In fact, the slowing down of the earth's rotation (which is normally our "master clock") has been measured as one-thousandth of a second per century by comparison with the planets, and we have no philosophically sound assurance that the planets keep "perfect time."

The cosmological principle leads mathematically to two kinds of time, one of which is speeding up relative to the other. Milne has shown that pendulum clocks, the earth, and the planets keep "dy-

namic" or clock time, while vibrating atoms and radioactive decay have constant period only in "kinematic" or atomic time. There is no philosophical reason for choosing one kind as the "correct" time; if we used a pendulum clock to time atoms we would find, after a very long interval, that the atoms are gradually speeding up in their vibration, if we used an atomic clock we would similarly find that the planets are slowing down in their orbits.

If this is correct—and no one has yet proved it otherwise—the age of the earth is 3 billion *atomic years* as determined from radioactive decay, but it is many more clock years, since in the past the clock year was shorter than the atomic year. (They are equal at present—by definition.)

The coincidence between the age of the earth and the time of recession of the spiral nebulae Milne explains as a result of the difference in these two kinds of time. Since the light we observe from a spiral 100 million light-years away left there 100 million years ago, we are seeing the atoms there ticking off the units of atomic time in use 100 million years ago. Compared to our present atoms, these early atoms ran slow; as a result, the light they emitted is redder than the light emitted now by similar atoms on the earth.

From this effect and his cosmological principle, Milne calculates that in the past infinite number of clock years there were 3 billion atomic years. The origin of the earth, and the time when all the spirals were close to our galaxy, both of them 3 billion atomic years ago, therefore occurred at the beginning of time (since one could hardly expect *more* than infinite time on the clock scale).

Now for Haldane's suggestion, which he calls "A Quantum Theory of the Origin of the Solar System." It is based, as its name implies, on the well-established quantum theory of radiation, and on a mathematical result of Milne's theory: that the universe, as measured in atomic time, has expanded with the velocity of light, starting from a point of zero radius 3 billion atomic years ago.

Since the universe started from zero radius, Haldane was able to pick an early enough instant, just a fraction of a second after the start of atomic time, when the whole universe was but a fraction of an inch in diameter—much smaller than the wave length of visible light—smaller, by far, than the wave length of X-rays or gamma rays. (These fractions are too small to write out easily; the first requires 72 zeros after the decimal point, the second, 62!) The wave lengths of radiation in existence in this small universe could scarcely have been bigger than the universe itself, Haldane reasoned, therefore the only radiation in existence was of these incredibly short wave lengths. But the basic principle of the quantum theory is that radiant energy comes only in packets, or "quanta," inversely proportional to the wave length in size. So, at this early instant all radiation was in

giant quanta of very small waves. And the energy of one of these giant quanta can easily be calculated as sufficient to knock one or more planets out of the sun. The even smaller waves at a somewhat earlier instant would have been in quanta with sufficient energy to tear apart stars, and even earlier, to tear apart the galaxies from some primordial globe of matter.

The details of this remarkable suggestion have been carried no farther, but Haldane's investigation points up one important general fact: whether or not Milne's new relativity is accepted, conditions at the time of the origin of the solar system were probably considerably different from those today. If Milne's cosmology is accepted, the relationship between radiation and matter was most radically different. It may seem that this last and most fantastic speculation—which can neither be completely explained nor fully evaluated here—contradicts our former conclusion that the solar system was formed from a rotating nebula of gas and dust. However, the condensation of the planets and the distribution of angular momentum (which have been so difficult to explain in all previous theories) may follow from further mathematical investigation of the first second of atomic time. In fact, if the details can be worked out rigorously, Haldane's suggestion may lead to confirmation of Milne's cosmology, which is as yet lacking.

In an echo of the introductory remarks it scarcely needs to be emphasized that we have no complete theory of the origin of the earth. The reader may be impressed with the diverse investigations involved and with the promise of the latest speculations; or he may notice the infinite regression implicit in any question of origins: if the planets were formed from dust or planetesimals, whence came the dust or planetesimals? if the dust and planetesimals came from a primordial nebula, whence came the primordial nebula? if the primordial nebula was formed by the absorption of a giant quantum by a fragment of matter, whence came the original matter and radiation in the universe? and so on, *ad infinitum* (clock time).

THE 200-INCH HALE TELESCOPE AND SOME PROBLEMS IT MAY SOLVE¹

BY EDWIN HUBBLE
Mount Wilson Observatory

[With 10 plates]

In 1609 Galileo turned his telescopes toward the sky. His favorite—it was the fifth, finished within 6 months of the first trial—was about 5 feet long and had a lens about 2 inches in diameter. It magnified nearly 30 times and its light-gathering power was equal to about 80 human eyes. He called it “Old Discoverer,” and with it he saw mountains on the moon, phases of Venus, four moons of Jupiter, and stars innumerable beyond the limit of the unaided eye.

It was then that the explorations of space began—the explorations that have swept outward in wave after wave as telescopes developed, until in our time we study a region of space so vast that it may be a fair sample of the universe itself. Today there is nearing completion a new telescope, far more powerful than any previously made, and it is proper to consider its significance both as an engineering achievement, and as an instrument for further explorations. With this end in view, I propose to discuss briefly the development of telescopes in general, the 200-inch in particular, and some of the problems it may help us to solve.

Galileo's optic tubes with single-lens objectives grew rapidly into telescopes from 20 to 25 feet long with lenses 2 to 3 inches in diameter. There the development stopped, for practical purposes, because of the engineering difficulties with still longer tubes.

The longer focal lengths were considered desirable in order to overcome color difficulties. With a single lens, each different color was brought to a focus at a different distance from the lens. Hence the image, when focused for any particular color, was blurred by the out-of-focus images in other colors. The long telescopes represented an attempt to spread out the images of different colors over so long a distance that one color could be focused with minimum interference

¹ Alexander F. Morrison lecture, delivered in Pasadena, Calif., April 8, 1947. Reprinted by permission, with slight alterations, from *Publications of the Astronomical Society of the Pacific*, vol. 59, No. 349, August 1947.

from the others. Telescopes 100, 150, and even 200 feet long were actually constructed, with lenses from 3 to 6 inches in diameter. These monstrous instruments, however, were too unwieldy for use, and the real work during the first century and a half after Galileo's time was done with the smaller telescopes.

Finally, in the middle of the eighteenth century, the color problem was solved by replacing the single-lens objective with a compound objective, each of whose separate components, made of different kinds of glass, canceled out most of the color effects of the other. These color-free (achromatic) lenses gave much better images and permitted the use of relatively short tubes for a lens of a given diameter. Telescopes immediately entered a new period of growth which culminated in the 40-inch lens, with a focal length of 63 feet, at the Yerkes Observatory in Wisconsin. The 40-inch was finished in 1892, and since that time developments have concerned lenses for special purposes rather than for greater light-gathering power. For technical reasons, it seems unlikely that larger lenses will be made in the foreseeable future.

This greatest of all lenses had been ordered originally by a group of enthusiasts here in southern California in connection with a plan for a "University System." The project did not fully materialize, and the unfinished telescope was bought and completed by the University of Chicago.

The very large telescopes of recent times, in which light-gathering power is the most important consideration, are all reflectors, not refractors. The light is funneled to a focus, not by refraction through a convex lens but by reflection from a concave mirror. These telescopes are free from color effects because all colors are reflected in the same way.

The first reflector was made by Isaac Newton in 1672, in a deliberate effort to avoid the color troubles of single-lens refractors. His first model had a burnished metal mirror, about an inch in diameter, figured to a concave spherical surface, and mounted at the bottom of a tube about 6 inches long. The image, which would lie in the middle of the upper end of the tube, was thrown to the side by a small plane mirror set at 45° to the axis, just below the focus. Newton presented the toy to the Royal Society, where it may still be seen, sitting on a volume of his famous *Principia*.

Although Newton's reflector avoided the color problem, it suffered another defect, known as spherical aberration, arising from the spherical surface of the main mirror. It was not until 50 years later when Hadley, in 1722, found a method of parabolizing concave mirrors, that the development of reflectors finally got under way. About 90 years ago metal mirrors were replaced by glass, silvered on the front surfaces. In our time aluminum has been substituted for silver,

low-expansion glasses have been developed, methods of parabolizing have been perfected, and engineering problems of constructing telescopes have been solved as they arose.

The 40-inch refractor was installed at Yerkes under the direction of George E. Hale. He clearly saw that, regardless of the success of this telescope, the quest for still greater light-gathering power depended upon mirrors rather than lenses. Refractors were preferable for certain types of work (including, for instance, visual resolution of double stars, precise measurement of position, wide-angle photography, etc.), but for light-gathering power, with all that it implies, the future lay with the reflector. Because the reflections are from the front surfaces, transparency and absolute homogeneity of the glass are not demanded; the mirror may be supported from the back and sides, instead of from the rims alone as in the case of lenses, and, of course, there are no color effects.

Hale took the lead in America in encouraging the development of large reflectors. A 24-inch of unusual perfection was made by G. W. Ritchey and installed at Yerkes. It proved so successful that plans for a 60-inch were immediately set in motion. When Hale left Yerkes to establish the Mount Wilson Observatory, he was able to transfer Ritchey and the unfinished 60-inch mirror to Pasadena, where the telescope was completed in 1908. The work of the 60-inch on Mount Wilson so fully justified the faith in larger reflectors that plans for a new one were immediately made, this time for a 100-inch mirror. This reflector, completed during the first World War, marked an important epoch in the history of astronomy. It is still the greatest telescope in operation. Four large reflectors with mirrors from 60 to 84 inches have since been completed (two in Canada and two in the United States), and others, including a 120-inch for Lick Observatory, are in process of planning or construction.

The 100-inch opened up new fields of investigation of the very first importance, and furnished glimpses of even richer fields beyond. If more light-gathering power were available, these more distant fields could be explored. In the face of this challenge the possibility of larger telescopes was the favorite topic of conversation among astronomers at Mount Wilson, and presumably at other places as well. We talked of 200 inches, or 300, and even dreamed of still more light. One of the group, F. G. Pease, drew tentative designs for a 300-inch, and demonstrated that the engineering features were not impossible.

Again Hale took the lead. Through his efforts funds were secured in 1928 in the form of a gift from the International Education Board to the California Institute of Technology for the establishment of an astronomical observatory and laboratory. An Observatory Council, with Hale as chairman, and with the greatest experts in the country as advisers, administered the details of the project. When Hale

dropped out, Max Mason took over the chairmanship. It was decided that a 200-inch reflector was as bold a step beyond the 100-inch as could be justified in view of the unknown problems, both optical and engineering, that might be encountered. Laboratories and shops were erected on the California Institute campus, a site for the observatory was found on Mount Palomar, a disk of pyrex glass was achieved by the Corning Glass Company, and the project proceeded steadily until it was interrupted by the war. Work was resumed soon after VJ-day, and the telescope has since been completed.

The proper fields for the 200-inch are determined primarily by its immense light-gathering power. Because adequate consideration of all the possible applications would require more time than is now available, I propose to limit the following discussion to three typical problems. These problems are, first, the existence of canals on Mars; second, the relative abundance of the chemical elements in stars; and, third, the large-scale structure of the universe. Each problem represents a particular aspect of light-gathering power, namely, resolution, dispersion, and depth penetration.

As a brief introduction, let me comment on the telescope itself. The mirror intercepts a beam of light 200 inches or $17\frac{1}{2}$ feet in diameter—in other words, it gathers as much light as a million human eyes, or four 100-inch reflectors. It funnels this light to an image at the primary focus, $55\frac{1}{2}$ feet in front of the mirror. There an image of the sky is formed such as you may see on the ground glass of a camera. This image may be examined visually with a microscope, recorded on a photographic plate, analyzed with a spectrograph, or studied by other techniques. Actually, most of the work will consist of direct photography or spectrum analysis. By using long time exposures, it is possible to photograph stars or nebulae several times fainter than can be seen in the eyepiece. For this reason, the 200-inch is best described as a huge camera.

Now let us consider some typical problems for the 200-inch. I shall start with a problem concerning a member of the solar system. The telescope will not be turned on the sun because of temperature effects—in some ways it would act as a burning glass. Nor does it offer any unique advantages for the study of the moon. In that field it will serve merely to improve data of a kind that can be got nearly as well with several other telescopes. In the field of planetary photography, however, the opportunities are unique because, for the first time, it may be possible to photograph all that the eye can see with a telescope of moderate size. An immediate application is to the highly controversial question of canals on Mars.

The canals are described as very fine, dark lines running along great circles, sometimes doubled, and often converging or crossing at spots called "oases." Such fine, hairlike patterns, superposed on the back-

ground of large, well-known markings, have been recorded by various trained visual observers, using telescopes of all sizes from 6 inches upward, during the whole of the past 70 years since Schiaparelli first reported them. The canal systems, if real, would almost necessarily imply the existence now or in the past of intelligent beings on Mars.

But other trained observers, again using telescopes of all sizes, report no trace of canals. E. E. Barnard, perhaps the greatest of the American visual observers, studied the planet over many years with the then largest telescopes in the world, including the 36-inch refractor at Lick, the 40-inch at Yerkes, and the 60-inch reflector at Mount Wilson, and, although he saw an immense amount of detail, he found no canals.

The two groups of observers flatly contradict each other, and since the observations are personal impressions neither group can demonstrate the validity of its assertions. Evidently the controversy must be resolved by photography. Once photographs are available on which the canals should appear if they are real features of the planet, the question will be settled beyond reasonable doubt. The test has not been possible as yet because existing equipment, although closely approaching the required standards, does not fulfill them. The 200-inch, however, should meet all the necessary conditions and settle the question.

The problem is as follows: Mars is a small object. The image at the primary focus of the 100-inch is less than $\frac{1}{16}$ inch at the most favorable oppositions, and less than $\frac{1}{8}$ inch at the long Cassegrain focus. In order to get an image large enough to serve as a critical test of fine markings (i. e., to make the resolution of the photographic plate comparable with the optical resolution of the telescope) it is necessary to use an enlarging lens. Thus the total light collected by the telescope is spread over a much larger, and correspondingly fainter, image. Furthermore, because of the atmosphere on Mars, it is necessary to photograph the surface markings through deep orange or red filters, still further reducing the effective brightness of the image. The reduction is so great that photographs with existing telescopes require time exposures instead of snapshots. The exposures may be only a second (or even a fraction of a second, with the 100-inch) but they are long enough to permit the dancing or shimmering of the image to smear out the finest detail.

You doubtless realize that a telescope magnifies the twinkling of stars along with everything else. Critical observations are restricted to periods of maximum steadiness (good seeing, as it is called), and even then, the shimmer is appreciable under high magnification. The eye can "hold" an image under these conditions, but photography with time exposures is helpless. The shimmer smears out the fine details. It is for this reason that, in the case of fine markings such

as the canals on Mars are said to be, the eye can see more than the photographic plate can record.

However, the 200-inch will collect so much light that, for the first time, it will be possible to photograph enlarged images through filters with snapshots. These exposures will be short enough to catch a dancing image at the end of a flicker—when it is momentarily at rest as it reverses direction. If many exposures are snapped on a movie film, a certain percentage of them may be expected to record what the eye can see (at least with telescopes of moderate sizes).

There is much more to the story, but it is too technical for the present discussion. But it can be said with some confidence that the 200-inch may settle the long-standing controversy concerning the canals on Mars.

The second problem I have selected for discussion involves spectrum analysis. You know, of course, that light reaches us as a jumble of waves of all different wave lengths, each representing a different color. It is possible, with prisms or gratings, to spread the colors out into an ordered sequence or spectrum, running from the long waves of the red to the short waves of the violet, and beyond in either direction. Such spectra of stars and nebulae show phenomena of profound significance at certain particular wave lengths. Spectrum analysis involves the isolation and study of these particular regions.

Your radio offers an analogy. With the tuning dial you run along the spectrum of radio waves and isolate a particular wave length in order to hear a particular station which is broadcasting on that wave length.

If there were no tuning device, and you heard all programs at once with a nonselective receiver, the result would be bedlam. The step from such a nightmare to the clear reception of messages from individual stations suggests the nature of the step in astronomy from the study of integrated light to spectrum analysis.

Light from stars and nebulae originates in atoms. There are as many kinds of atoms as there are chemical elements, and the atoms may have various stable states. Each stable state of each kind of atom represents a set of broadcasting stations, sending messages concerning the nature of the atoms and the physical conditions under which they exist. By tuning in and reading these messages, it is possible to identify chemical elements, to determine temperatures, pressures, and other physical attributes, and even to measure motion in the line of sight (radial velocity).

But in order to read the messages clearly it is necessary to achieve precise tuning—that is, to spread out the spectrum on the maximum possible scale. It is here that the great light-gathering power of the 200-inch offers new possibilities.

The length over which a spectrum can be spread, and still remain bright enough to be photographed, depends upon the brightness of the object. The sun has been spread out over a spectrum about 50 feet long from red to violet; the brightest stars, over about 3 feet, and the faintest naked-eye stars over about 1 foot. The shortest spectra giving useful information are about one-tenth of an inch long, and have been obtained from stars and nebulae about a hundred thousand times fainter than the faintest naked-eye stars. With the 200-inch, all the stellar and nebular spectra can be lengthened about four times, and consequently the analysis can be carried out much more precisely than was hitherto possible.

One new field, now faintly glimpsed, can be explored rather fully. The important data are the relative abundances of the different chemical elements in different kinds of stars. These data are derived from the comparative study of the different stations (or lines) due to different chemical elements in a spectrum, and require the longest practical spectra (the highest possible dispersion) for adequate analysis.

There is reason to believe that more than 99 percent of the atoms in the universe are hydrogen. Even by weight, hydrogen, with the simplest and lightest of all atoms, probably contributes a large fraction of the total matter in the universe. There are insistent suggestions that the relative abundance of hydrogen varies considerably from star to star. There is also some reason to suppose that the relative abundance of other elements does not vary widely in the stars, although the physical conditions of the stars do vary widely (from giants to dwarfs, from hot blue stars to cool red stars). The supposition rests mainly on negative evidence and requires further study with powerful instruments.

It is believed that the 200-inch alone can adequately explore this field, now dimly outlined with existing telescopes. What is now suggested by analysis of three or four of the very brightest stars can be critically tested in these objects, and the study can be extended in a comparable way over a large sample collection of stars in general. We cannot predict the final results of the exploration. They may represent the next major chapter in the development of our knowledge of the universe, or they may prove to be relatively trivial. But the unexplored field looms as a challenge, and the challenge will be met.

The data are immensely important because they bear directly on two very fundamental problems, namely, the source of stellar energy and the origin of chemical elements.

Geologists, studying the history of the earth's surface, assure us that the sun has been pouring out energy at a fairly constant rate over the last several hundred million years at least. Possible sources for the unfailing supply were not only unknown but were unimagined,

until the modern science of nuclear physics was developed. Now explanations may be sought over a wide range of nuclear reactions giving various lifetimes to stars up to the limit set by Einstein's famous formula,

$$\text{energy} = \text{mass} \times (\text{velocity of light})^2$$

For instance, if the whole of the sun's mass were transformed directly into energy, the sun could radiate at the present rate for a million million years. But, if nuclear reactions supplied the energy, the possible lifetime (with the present rate of radiation) would be reduced according to the particular reaction involved.

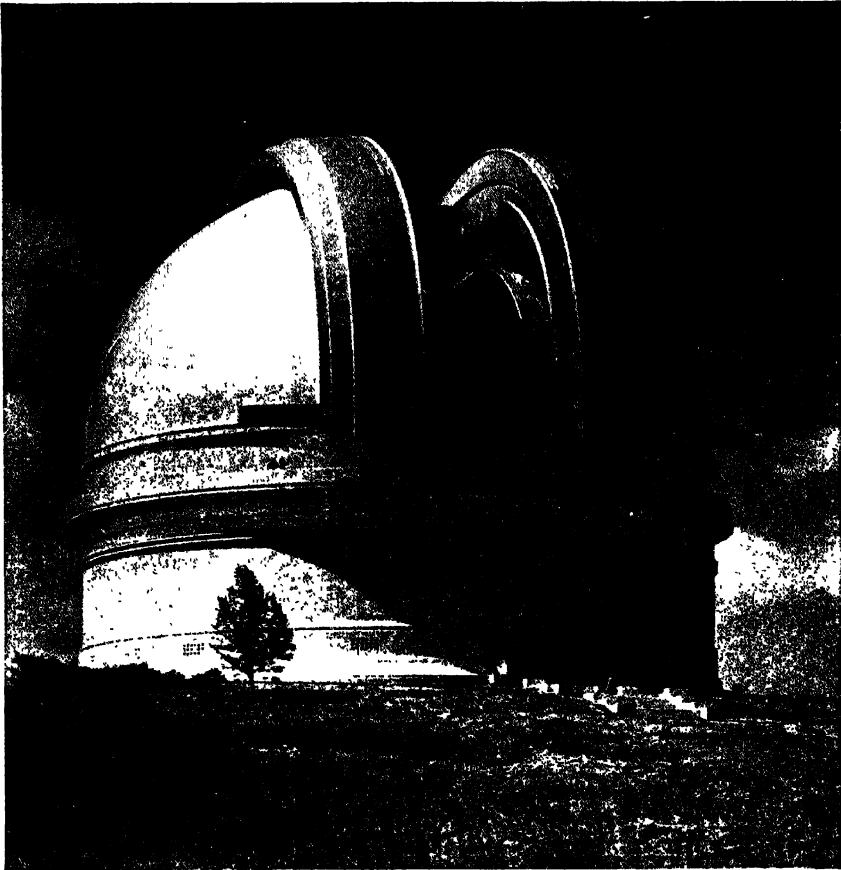
The nuclear reactions, in general, produce the transmutation of elements—the old dream of the alchemists. The most plausible of the current theories concerning the source of the sun's energy, proposed by H. Bethe, is based on the carbon cycle in which, because of the presence of carbon at temperatures found in the sun, hydrogen nuclei may combine to form helium, releasing energy in the process. One test of the theory is furnished by a comparison of the relative abundance of the different isotopes of carbon actually observed in the sun with the relative abundances involved in the carbon cycle.

In a vaguely analogous way, it is possible to speculate on the building up of all elements from the primitive hydrogen atoms, and these speculations may be guided by the observed relative abundances of elements in stars of widely different physical characteristics.

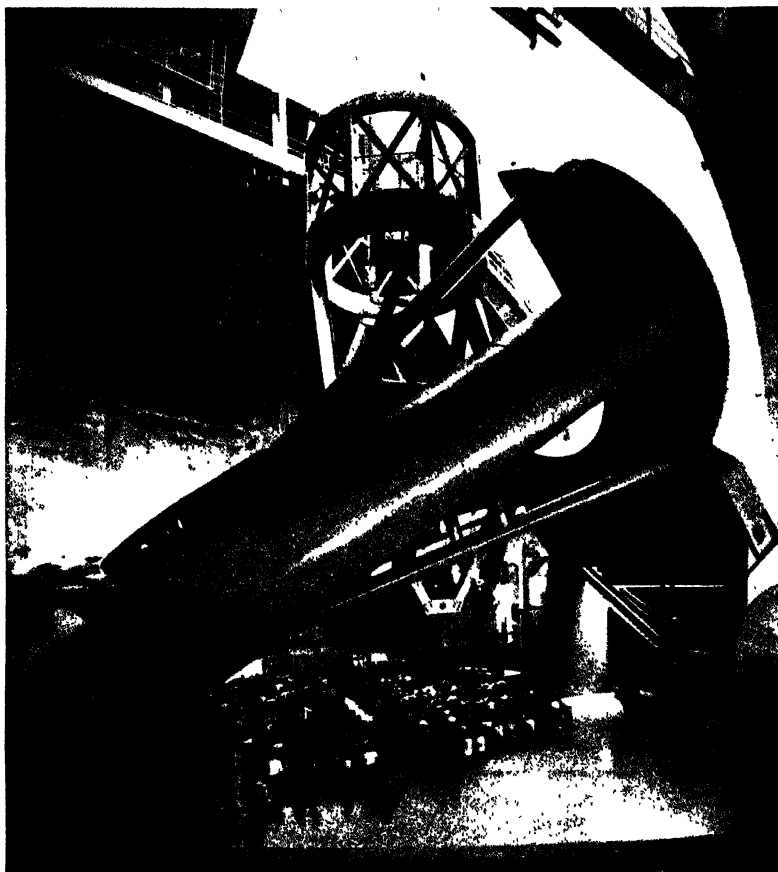
Thus the data on abundances, derived from large-scale spectra, bear directly on all theories concerning the source of stellar energy, the origin of chemical elements, the past history of the universe, and its future evolution.

The third unique field of investigation for the 200-inch is cosmology—the structure and behavior of the universe as a whole. Astronomers hope that the observable region of space—the region that can be observed with telescopes—is a fair sample of the universe, and they attempt to infer the nature of the universe from the observed characteristics of the sample. The 200-inch, because of its great light-gathering power, should penetrate into space about twice as far as the 100-inch, and consequently will permit us to explore a volume of space about eight times that now available. The probability that the observable region may be a fair sample of the universe will thus be greatly increased.

It was the 100-inch that opened this new field and prepared the way for the new telescope. The picture developed rather suddenly during the 1920's. The sun with its family of planets seems isolated and lonely in space, but we know that it is merely one of the stars—one of several thousand million stars which, together, form the stellar system. This system is a swarm of stars which drifts through space

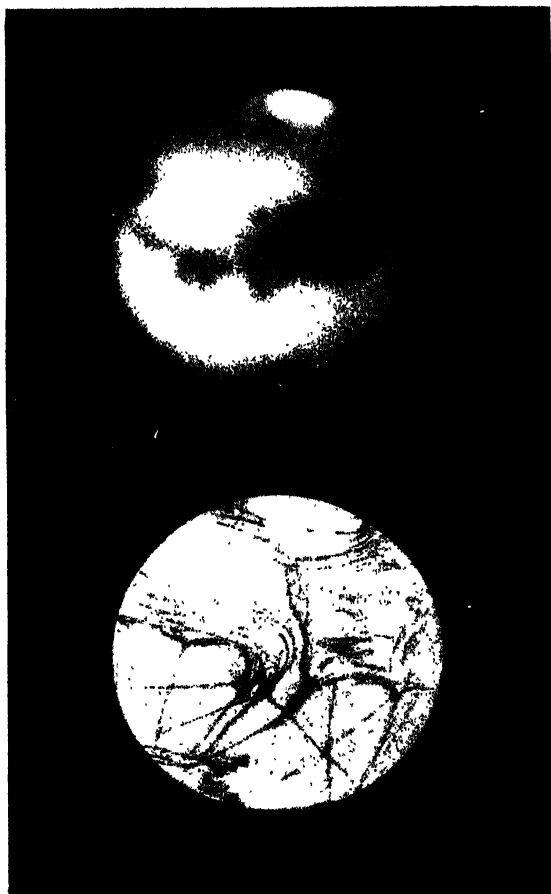


DOME OF THE 200-INCH TELESCOPE ON PALOMAR MOUNTAIN



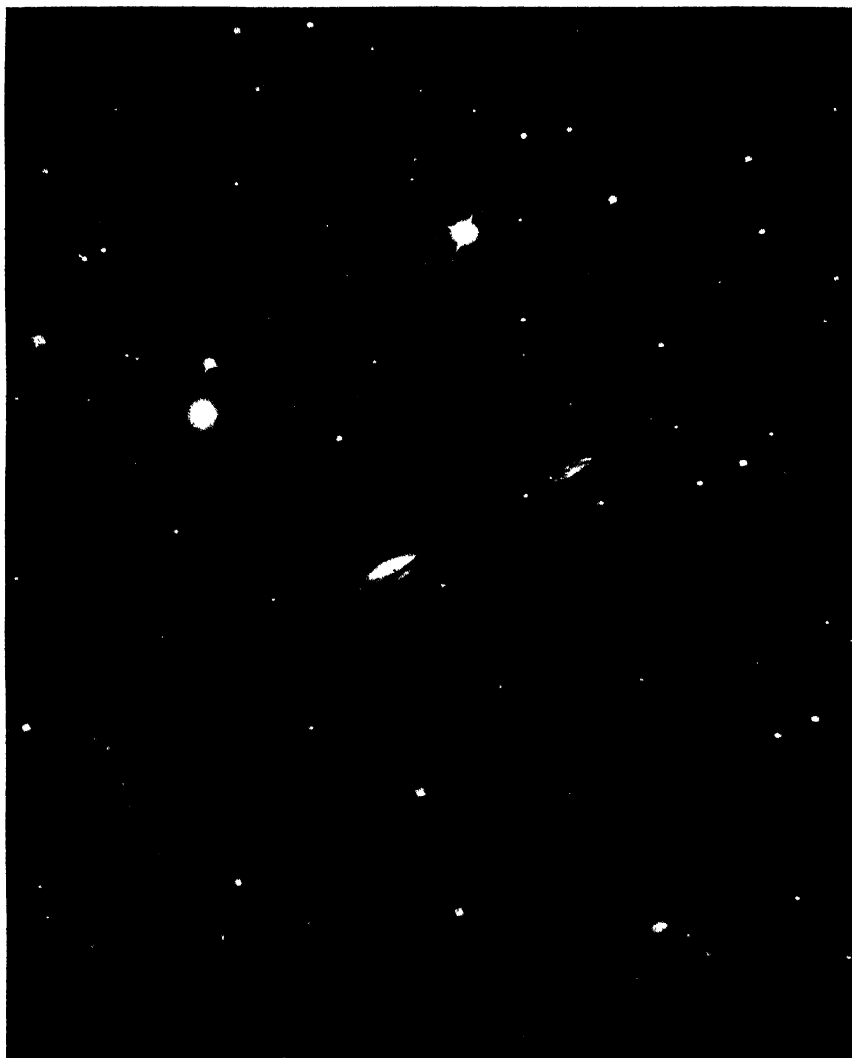
200-INCH HALE TELESCOPE

Meeting of the American Astronomical Society and the Astronomical Society
of the Pacific on July 1, 1948.



MARS

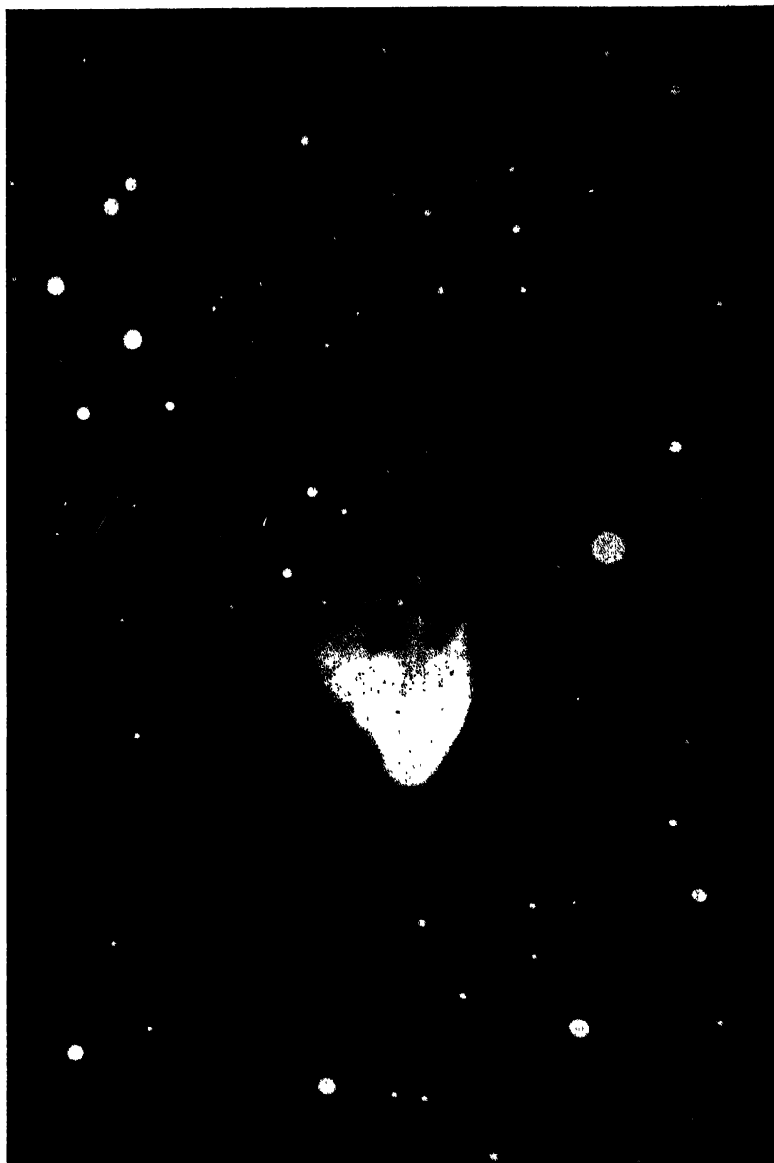
Upper. Photograph with 100-inch reflector, September 2, 1924.
Lower. Drawing by Pettit with 20-inch reflector, July 12, 1939. These typical pictures illustrate the fact that as yet photography does not furnish an objective test of the existence of "canals" on Mars.



EXTRAGALACTIC NEBULAE

These nebulae are examples of the stellar systems which serve as landmarks in the exploration of the universe. The group above (NGC 3185, 3187, 3190, 3193) is at a distance of about 8 million light-years and appears to be receding from us at the rate of about 850 miles per second.

N



NGC 2261

The first photograph made with the 200-inch Hale telescope.

N

E

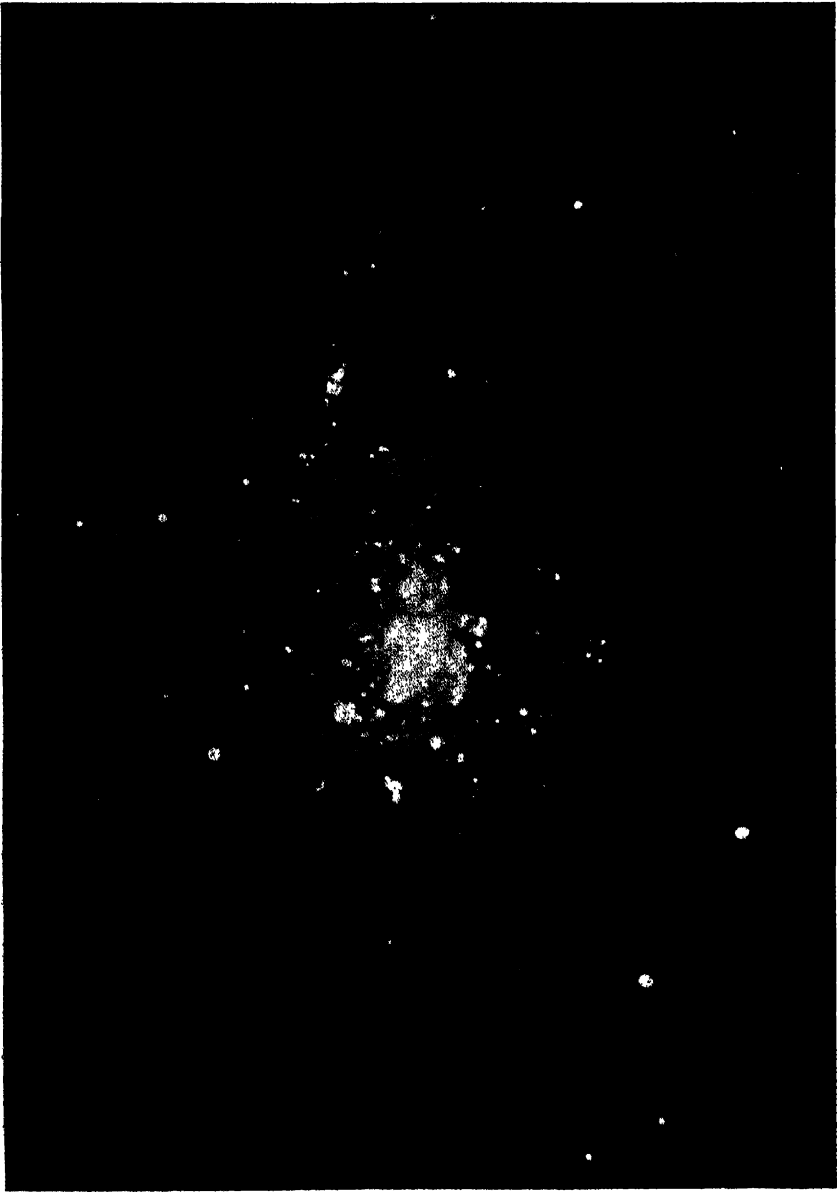


REGION IN SELECTED AREA 57



MESSIER 87 (NGC 4486)

N



NGC 5204

N



W

NGC 3359

S

W



MESSIER 3 (NGC 5272)

as a swarm of bees drifts through the air. From our position somewhere within the system, we look out through the swarm of stars, past the boundaries, into the universe beyond.

Those outer regions are empty for the most part—vast stretches of empty space. But here and there, scattered at immense intervals, we find other stellar systems comparable with our own. They are so remote that individual stars can be seen only in a few of the nearest systems. In general they appear as faint patches of light, resembling tiny clouds, and have long been called by the Latin word for clouds—that is, “nebulae.”

We now know that these nebulae are huge stellar systems averaging about a hundred million times as bright as the sun. They are the true inhabitants of space—vast beacons that serve as landmarks for the exploration of the universe. We see a few that appear large and bright. These are the nearer nebulae. Then we find them smaller and fainter in constantly increasing numbers, and we know we are reaching out into space farther and ever farther, until, with the faintest nebulae that can be detected with the largest telescope, we have reached the frontiers of the observable region.

This region has been explored with the 100-inch out to distances so remote that light, speeding at 186,000 miles per second, requires 500 million years to make the journey. Thus the observable region at present is a sphere, centered on the observer, with a radius of about 500 million light-years. Throughout this sphere about a hundred million nebulae are scattered, each a stellar system comparable to our own system of the Milky Way.

The study of this observable region as a sample of the universe has led to the recognition of two large-scale features. The first feature is homogeneity. The nebulae are scattered singly, in groups, and even in great clusters, but when very large volumes of space are compared, their contents are found to be quite similar. On the grand scale, the observable region appears to be very much the same, in all directions and at all distances.

The second characteristic is the fact that light waves from distant nebulae seem to grow longer in proportion to the distance they have traveled. It is as though the stations on your radio dial were all shifted toward the longer wave lengths in proportion to the distances of the stations. In the nebular spectra the stations (or lines) are shifted toward the red, and these red-shifts vary directly with distance—an approximately linear relation.

The red-shifts are most easily interpreted as evidence of motion in the line of sight away from the earth—as evidence that the nebulae in all directions are rushing away from us, and that the farther away they are, the faster they are receding. This interpretation lends itself directly to theories of an expanding universe. The interpretation is

not universally accepted, but even the most cautious of us admit that red-shifts are evidence either of an expanding universe or of some hitherto unknown principle of nature.

The two observed characteristics of the observable region, namely, the approximately uniform distribution and the approximately linear law of red-shifts, must be satisfied by any theory of the universe. They are the only observational results on the grand scale that can be used as tests. They serve to eliminate many theories formerly developed on insufficient data, but several modern theories survive the tests. These latter theories all permit the observed features in a limited region near the observer but they predict that departures from the simple approximate laws of distribution and of red-shifts will be found when the measures are extended to greater distances. These departures differ from theory to theory, and, if the measures can be extended to the necessary distance, will distinguish the correct theory from the false.

Thus the most important observational problems in cosmology may be described as the small, second-order effects of great distances. The nebulae appear to be distributed in a roughly uniform manner and the red-shifts appear to be roughly proportional to distance, out to the limits of the 100-inch. The next step is to determine these features more precisely over the limited range of the 100-inch and approximately out to far greater distances.

Attempts have been made to attain the necessary precision with the 100-inch, and the results appear to be significant. If they are valid, it seems likely that red-shifts may not be due to an expanding universe, and much of the current speculation on the structure of the universe may require re-examination. The significant data, however, were necessarily obtained at the very limit of a single instrument, and there were no possible means of checking the results by independent evidence. Therefore the results must be accepted for the present as suggestive rather than definitive.

The problem is essentially one for the 200-inch. This new telescope will penetrate into space out to a thousand million light-years, and the second-order effects of great distance will be so conspicuous that they cannot be missed.

As a particular and final example, let me mention the effects of increasing red-shifts on apparent brightness. It is well known that a rapidly receding light appears fainter than a similar, but stationary, light at the same momentary distance. The reason is that the stream of light-quanta from the moving light is thinned out by the recession so that fewer quanta per second reach the observer. Since brightness is measured by the rate of arrival of quanta, the receding light appears abnormally faint.

Actually the dimming factor (the reduction of apparent brightness) is a simple fraction represented by velocity of recession divided by the velocity of light. Recession at one one-hundredth the velocity of light reduces the apparent brightness by 1 percent; at one-tenth the velocity of light, by 10 percent, and so on. Thus the effects of recession would be negligible until velocities of several hundred miles per second were reached. The effects would be appreciable at a few thousand miles per second, and conspicuous at several tens of thousands of miles per second.

If red-shifts are evidence of actual recession, the dimming factors should become appreciable near the limits of measurement with the 100-inch and should be conspicuous near the limit of the 200-inch. At the very limits of direct photographs with the 200-inch, the factor should approach the order of 40 to 50 percent, and should be unmistakable.

We may predict with confidence that the 200-inch will tell us whether the red-shifts must be accepted as evidence of a rapidly expanding universe, or attributed to some new principle of nature. Whatever the answer may be, the result will be welcomed as another major contribution to the exploration of the universe.

I have mentioned the three specific problems of canals on Mars, relative abundance of chemical elements in stars, and the nature of the red-shift, because they illustrate the unique powers of the 200-inch telescope in three aspects, namely, resolution, dispersion, and space penetration.

Because these problems are of first importance, and can be solved, they, together with others of a similar kind, will be included in the initial research programs. The solutions of these problems alone will fully justify the construction of the telescope.

But such a program is merely a logical beginning—the first carefully considered stage in the exploration of vast unknown regions of the universe. As the darkness is pushed back, greater problems will doubtless emerge which we cannot now foresee.

FIRST PHOTOGRAPHS WITH THE 200-INCH HALE TELESCOPE*

The first photographs with the 200-inch Hale reflector on Palomar, made under normal observing conditions, confirm the most optimistic predictions of its designers. Such a statement, as usual, requires some explanation. The photographs were made as routine tests to record progress in the tedious program of adjustments. Seeing was never better than "average," the aluminum coat was dusty and grimy, and the mirror showed a turned-up edge. These handicaps, of course,

* A later article by Dr. Hubble from the *Publications of the Astronomical Society of the Pacific*, vol. 61, No. 360, June 1949.

will be eliminated or avoided in time, but during the tests they caused some loss of light and appreciable loss of definition. Nevertheless, the test plates record stars and nebulae fully 1.5 magnitudes fainter than the extreme limit of the 100-inch reflector on Mount Wilson. The faintest star images, on the better plates, were, however, a little more than 1 inch in diameter, and, at the threshold, it was sometimes difficult to distinguish with certainty between stars and nebulae.

Thus the 200-inch has registered already the full gain in light-gathering power corresponding to the size of the main mirror. The slight additional gain that may be expected with a clean, sensibly perfect mirror surface will be accounted for by the absence of a Newtonian flat and by the very transparent sky over Palomar.

The greatest improvement in the future will be in definition, as indicated by the size of faint star images. Definition is very sensitive to the seeing, and, while the test plates approached the definition to be expected under average conditions, they indicated that the mirror is not yet in shape to operate at maximum efficiency on the rare nights of fine seeing. The trouble arises from the turned-up edge and can be eliminated by the retouching now in progress. The improved definition will be significant, particularly for distinguishing nebulae from stars at the threshold of long exposures. In the higher latitudes, the telescope records many more nebulae than stars.

The turned-up edge was well known from Hartman tests, and its effects could be predicted with some confidence. The photographs were made primarily to confirm and record these effects. However, the first plates were so impressive that a set of full exposures was made to serve as a record of performance before the mirror was removed for retouching. About 60 photographs were assembled over the 3 months from January 26 to April 28, as opportunities arose during the normal program of adjustments. Of this number, perhaps half a dozen represent full exposures under average seeing conditions, and a like number show good performance with reduced apertures or with a Ross correcting lens for enlarging the usable field. Selections from the files are illustrated in plates 5 to 10, and comments on them are given below. The full aperture (200-inch) and Eastman 103a-O emulsions were used in all exposures except those to which special references are made in the comments. The scale of the original negatives is about $1\text{ mm}=12''$.

Plate 5, NGC2261; R.A.= $6^{\text{h}}36^{\text{m}}6$, Decl.= $+8^{\circ}47'$ (1950); Jan. 26, 1949; 15 min. exposure, poor seeing; enlarged $3\frac{1}{4}\times$.

This plate shows the first of the photographs with the Hale telescope. It is recorded as PH-1-H (i. e., Palomar, Hale, No. 1, followed by the initial of the observer). It was made under poor conditions as a preliminary test of the mechanical operations and procedures involved in direct photography at the prime focus. The trial was

successful, except for the large size of the star images produced by the poor seeing. The exposure was made on January 26, 1949, about 10 p. m., after waiting more than a week for a break in the weather.

The object, NGC2261, is a well-known, variable galactic nebula—a comet-shaped mass with the variable star, R Monocerotis, at the apex.

Plate 6, S.A. 57; R.A.=13^h6^m3, Decl.=+29°37' (1950); Jan. 27, 1949; 60 min. exposure, seeing average; enlarged 7¼×; center is 2½ N. and ¾ W. of BD+30°2371. This selected area contains one of the most reliable magnitude sequences available for faint stars extending to the 21st magnitude. Exposures of 1 minute registered stars to about 19.7, and of 3 minutes, to about 20.7. Exposures of 5 or 6 minutes reached the extreme limits of the 100-inch, beyond the end of the sequence. From these data it is estimated that the 60-minute exposures permitted by the dark sky above Palomar reached at least 1.5 magnitude beyond the 100-inch.

The threshold of the plate is dominated by nebulae rather than by stars, and this fact emphasizes the tremendous range of the telescope. Some of the faintest nebulae recorded are presumably at about twice the distance reached with the 100-inch or, in round numbers, at about 1,000 million light-years. This figure, of course, refers to average nebulae. Individual images on the photograph may represent dwarf nebulae at lesser distances or giant nebulae, even more remote.

Plate 7, Messier 87 (NGC4486); R.A.=12^h28^m3, Decl.=+12°42' (1950); Apr. 27, 1949; exposure 45 min., seeing average; enlarged 8×.

The object is one of the brightest members of the Virgo cluster of nebulae, whose distance is of the order of 7.5 million light-years. It is classified as a peculiar elliptical nebula (E0p). The photograph shows the nebula, presumably a globular mass of type II stars (i. e., stars similar to those in globular star clusters), surrounded by an extensive, tenuous atmosphere of supergiant stars. This phenomenon was suggested by the best photographs made with the 100-inch on Mount Wilson, but is conspicuous on the 200-inch plate.

Plate 8, NGC5204; R.A.=13^h28^m0, Decl.=+58°38' (1950); Jan. 31, 1949; exposure 30 min., seeing average; enlarged 4×.

The object is a dwarf, late-type spiral in Ursa Major, at an estimated distance of less than 3 million light-years. The plate is included to show the ability of the telescope to resolve the neighboring stellar systems so that the brighter stars can be studied individually.

Photographs of several of the larger spirals, such as M 81, NGC2403, etc., have been made, but the coma-free field of the telescope at full aperture is so small (about 5 minutes of arc in diameter) that the plates are not suitable for reproduction on a scale sufficient to show the resolution to advantage.

Plate 9, NGC3359; R.A.=10^h43^m4, Decl.=+63°20' (1950); Apr. 27, 1949; exposure 45 min., seeing average; enlarged 3×.

This late-type barrel spiral is an isolated stellar system or, possibly, an out-ri-der of the Ursa Major cloud of bright nebulae, and its distance is of the order of 5 million light-years. The plate is included to illustrate the resolution of fairly distant nebulae, and the opportunities now available for the study of the very brightest stars in stellar systems.

Plate 10, Messier 3 (NGC5272); R.A.=13^h39^m5, Decl.=+28°38' (1950); Apr. 21, 1949; exposure 3 min., made with an aperture of 160 inches, and a Ross correcting lens; seeing average; enlarged 8×.

This plate, of a well-known globular star cluster, is included to illustrate the use of a Ross correcting lens, placed a few inches in front of the plate, to enlarge the coma-free field of the telescope. The lens performed well with the 160-inch aperture but, with the full 200-inch, it exaggerated the effects of the turned-up edge of the main mirror. The provisional mounting of the lens did not permit the use of a guiding eyepiece, so the plate shows the successful performance of the tracking mechanism of the telescope during an unguided exposure of 3 minutes. The usable field with this correcting lens is more than 15 minutes of arc in diameter.

THE DETERMINATION OF PRECISE TIME ¹

BY SIR HAROLD SPENCER JONES
Astronomer Royal of Great Britain

Of the three fundamental physical units, there is an essential distinction between the unit of time and the units of mass and length. The units of mass and length are represented by material standards to which any mass or length can be related, either directly or indirectly. But the unit of time cannot be represented by any material standard. For practical purposes time can be thought of in the Newtonian sense as something which flows uniformly. The passage of time can be marked by a clock, and any simple natural phenomenon which obeys one definite law without perturbation might be used to mark off equal intervals of time and therefore to serve as a clock. The rotation of the earth provides us with a natural clock. We shall see later that it is not a perfect clock, but that it is sufficiently uniform for almost all practical purposes; it has, moreover, the great advantage of never stopping.

We can therefore define the unit of time as the period of rotation of the earth. Some reference object must be selected against which to measure the rotation. For the purposes of everyday life, time must be related to the sun, whose rising and setting gives the alternation of daytime and nighttime. The day defined by the rotation of the earth with respect to the sun is called the true solar day; it is the interval between two consecutive transits of the sun across the meridian of any place. With this unit, true solar time is obtained by dividing the true solar day into 24 hours and calling the instant of meridian passage of the sun 12 hours. The time given by a sundial is true solar time. For practical purposes, however, true solar time is not convenient; because the motion of the sun across the heavens is not uniform, the length of the solar day varies in length throughout the year. For civil purposes, therefore, a mean solar day is used, whose length is equal to the average length of the true solar days throughout the year. The time based on the mean solar day as unit is called mean solar time. The relationship between mean solar time and true solar time at some particular instant is defined by means of

¹ Sixteenth Arthur lecture, given under the auspices of the Smithsonian Institution April 14, 1949.

a convention, into the details of which I need not enter. The extreme differences between mean and true solar times range from $16\frac{1}{2}$ minutes about November 3, when true noon precedes mean moon, to $14\frac{1}{2}$ minutes about February 12, when true noon follows mean moon.

Astronomers, however, find it more convenient to determine time by the observation of the stars. There are many stars but only one sun and, moreover, the time of transit of a star can be determined more accurately than the time of transit of the sun. The sidereal day is defined by the rotation of the earth relative to the stars. It is about 4 minutes shorter than the solar day. If we imagine the sun and a star to be on the meridian of some particular place at the same instant, then after the lapse of one sidereal day the star will again be on the meridian; but, because of the orbital motion of the earth round the sun, the earth will have to turn a little more in order to bring the sun onto the meridian. In the course of a year the earth completes its orbit around the sun and there must consequently be exactly one more sidereal day in the year than mean solar days.

If the relative positions of a number of stars in the equatorial region of the sky have been accurately determined, we can think of them as equivalent to the graduations on the face of a clock. As the earth rotates, a telescope, fixed so as to be able to move only in the meridian, will sweep across these stars in turn, each at a definite specific instant of sidereal time. By observing the transit of stars whose positions are known, the sidereal times at the instants of meridian transit are therefore determined. The beginning of the sidereal day or, in other words, Oh. of sidereal time, is defined by the transit of the point in the sky at which the ecliptic crosses the equator from south to north; this point is called the vernal equinox or the First Point of Aries.

By defining the commencement of the sidereal day in this manner, we are provided with a means for converting from sidereal time to mean solar time, which is required for the purposes of everyday life. But it has one inconvenience. The First Point of Aries is not fixed relative to the stars. It has a slow retrograde motion, due to the precessional motion of the earth's axis, and superposed on this uniform motion is a slow to-and-fro drift, caused by the nutational or nodding motion of the axis. The nutation depends upon the relative positions and distances of the sun and moon from the earth. The principal term in the nutation has a period of about 18 years and a semi-amplitude of about 1 second of time. There is also a 6-monthly term amounting to 0.08 second and a number of short-period terms amounting to 0.020 second, of which the principal term has a period of 2 weeks. The precision of modern clocks is such that these small terms cannot be neglected. The true sidereal day, measured relative to the true position of the First Point of Aries, is therefore not absolutely uniform in length, and it is necessary to introduce the con-

ception of mean sidereal time, measured relative to the mean position of the First Point of Aries. Actual observation of the stars provides the astronomer with true sidereal time, which he then has to correct for the nutation to obtain mean or uniform sidereal time.

The determinations of time by astronomical observations are used to control the performance of a standard clock, determining its error at a specific instant and the rate of increase or decrease of that error, the clock then being used to obtain the time at other instants. This usually involves extrapolation to some time subsequent to the latest observation. For such extrapolation to be accurate, the time determinations must not be affected by serious errors and the standard clock must be of high precision. The determination of precise time therefore involves two problems, the determination with high accuracy of the time at specific instants and the development of time-keepers of very high precision.

The sidereal time of the transit of a star across the meridian is equal to the right ascension of the star. Sidereal time can therefore be determined by observing the times of meridian transit of stars of known right ascension. The conventional method of making the observations has been to use a transit instrument. This consists of a telescope, mounted on an axis at each end of which is a cylindrical pivot. The pivots rest in fixed bearings, adjusted so that the common axis of the pivots is as nearly as possible horizontal and pointing in an east-west direction. If the axis of the pivots were exactly horizontal and in the east-west direction and if the optical and mechanical axes of the telescope coincided, the axis of the telescope would be in the meridian plane, whatever direction the telescope was pointing to. This ideal condition is never achieved and there are always small errors of level, of azimuth, and of collimation. These adjustments are liable to continual change; there are slow seasonal changes, associated with changes of temperature and possibly also with sub-surface moisture; there are also more rapid changes, which are correlated with changes of circumambient temperature and with the direction of the wind. To control these changes frequent observations of level, of azimuth, and of collimation are essential, which take up a disproportionate amount of the observing time. The error of collimation can, however, be eliminated if the telescope is reversed in its bearings in the middle of each transit, half the transit being observed before reversal and the other half after reversal. It is not possible to reverse large transit instruments sufficiently quickly and it has accordingly become customary to use small transit instruments, which can be rapidly reversed, for the determination of time; as it is the brighter stars which are observed, a large aperture is not needed.

There are other factors which have also to be taken into consideration. The pivots will never be absolutely cylindrical; their figures

have to be determined with great accuracy and appropriate corrections made to the observations. Flexure of the axis can cause troublesome systematic errors. If the horizontal axis is not equally stiff in all directions, its flexure will vary according to the direction in which the telescope is pointed. If the two halves are not equally stiff, the telescope will be twisted from the meridian by a variable amount. Personal equations between different observers are somewhat troublesome, though they do not exceed a few hundredths of a second when the so-called impersonal micrometer is used. Before its introduction, the method of observing was for the observer to press a hand-tapper at the instant the star crossed each of a number of vertical spider wires in the focal plane of the telescope; by so doing, he closed an electric circuit which sent a current to a recording chronograph, which recorded not only the signals from the telescope but also time signals, every second or alternate seconds, from the clock. The instants of the star crossing the wires could then be read off at leisure after the observations had been completed. With this method of observing, the times determined by different observers could differ by as much as half a second. The reason is easy to see; one observer might wait until he saw the star actually bisected by the wire before he pressed the tapper, with the result that, because of the time required for the message to travel from his brain to his eye and to be converted into muscular action, his signal would inevitably be late; another observer would, as it were, shoot the flying bird, gauging the rate of motion of the star so that his tap is made as nearly as possible at the instant at which the star is actually bisected. The personal equations can be determined by what are called personal equation machines; the transit of an artificial star is observed, the times at which the star is at certain positions during the transit being compared with the observed times. Although an observer will unconsciously form a fixed habit in observing so that his personal equation remains substantially constant, small variations, depending upon the physical condition of the observer, do occur.

The method of observing now almost universally employed is to have a single movable wire in the micrometer eyepiece instead of a number of fixed wires. The wire can be traveled along by the observer, who adjusts its speed so as to keep the star continually bisected by the wire. As the wire moves along, contacts are automatically made in certain positions, sending signals which are recorded on the chronograph. In order to relieve the observer of some of the strain of maintaining a uniform motion of the wire, it is now common to drive the wire mechanically at the speed appropriate to the motion of the star, using an electric motor with some form of continuously variable gearing. With this method of observing, the personal equations of different observers are very small, usually not

more than two or three hundredths of a second; it is for this reason that this form of micrometer is called the "impersonal" micrometer. Small though these residual personal equations are, they remain remarkably constant and can be determined by personal equation machines. They seem to arise from two causes: there is "bisection error," an observer systematically bisecting an image to the right or to the left of its center; this error changes sign at the zenith with instruments in which the observer changes the direction in which he faces, according to whether he is observing a north or a south star; there is also "following error," an observer systematically setting the wire in front of or behind the center of a moving image. This error does not change sign at the zenith.

If the pivots are not exactly cylindrical, the telescope will be twisted out of the meridian by an amount varying with its position. The figures of the pivots must therefore be determined with great accuracy and appropriate corrections applied to the observed times of transit. The figures of the pivots must be determined at intervals, as they may change slowly in the course of use through wear. Other variable errors can be introduced through slight mechanical imperfections in the telescope; if there is the slightest play in the eyepiece micrometer or in the objective, errors will be introduced which will vary with the position of the telescope.

When all the possible sources of error which can affect observations with a transit instrument are borne in mind, it is rather surprising that the observations are as accurate as they are. The probable error of a single time determination is usually about two-hundredths of a second. This was quite accurate enough before the era of clocks of high precision and before there were any practical requirements for very precise time. The scatter of the observations is, however, inconveniently large for the adequate control of the performance of the modern quartz-crystal clock. For these reasons the conventional transit instrument is likely to be gradually replaced for the purpose of time determination by some other type of instrument. Several modifications of the transit instrument have been considered which eliminate or minimize some of its disadvantages. The most accurate results are given, however, by an entirely different instrument known as the photographic zenith tube. It consists of a fixed vertical telescope pointing to the zenith, which has a mercury horizon at the bottom of its tube, whose purpose is to reflect the light from a star to a focus in the plane of the second principal point of the objective. The fundamental principle of the instrument was due to Sir George Airy, who first used it for the reflex zenith tube at Greenwich: when the light is brought to a focus accurately in the plane of the second principal point of the objective, the results are unaffected by tilt of the telescope. The troublesome error of level is therefore immaterial, while any error

of azimuth does not affect observations made in the zenith. The telescope is constructed so that the objective and the plate holder can be rotated through 180° , the observations being made photographically in order to eliminate personal equations and to give greater accuracy. Suppose two exposures are given on a star at times which are symmetrical about the time of meridian transit, the objective and the photographic plate being rotated through 180° between them. The two images will lie on a line exactly parallel to the meridian. If, however, the two times of exposure are not exactly symmetrical, the images will be slightly staggered; by measuring the staggering and knowing the clock times of the two exposures, the clock time of meridian transit can be inferred.

In practice an exposure of finite length is required to give a measurable image on the plate. During this exposure the plate holder is traveled along at the speed appropriate to the motion of the star, signals being sent to the chronograph at certain definite positions of the plate holder. After reversal the plate carriage retraces its path, and signals are sent during the course of the second exposure at the same positions.

With this design of instrument, collimation error does not enter, there are no pivot errors to be considered, and the various sources of error inherent in a movable instrument are avoided. At the Naval Observatory, Washington, a photographic zenith tube, designed and used by F. E. Ross originally for the determination of the variations of latitude, has been used for some years for the determination of time. An instrument on the same general principle, but differing materially in details of design, is in an advanced stage of construction for the Royal Greenwich Observatory. The errors of time determination should not exceed 2 or 3 milliseconds, which will permit a tight control of the performance of the observatory clocks.

For the purpose of time determination it is necessary to assume positions for the stars which are observed. These positions will have random errors, whose effects can be reduced by observing sufficient stars. But they may also be affected by systematic errors; if, for instance, the errors vary with right ascension they will introduce a spurious systematic variation in the derived clock error through the year. For the purpose of time determinations and in order that the times determined at different observatories can be directly compared, there is an international agreement to use the positions of the stars given in the fundamental star catalog known as the FK3. These are bright stars, whereas with the photographic zenith tube, inasmuch as observations are restricted to a narrow belt at the zenith, it is necessary to use fainter stars. Their positions must therefore be determined by transit circle observations and tied on to the FK3 system. The photographic observations will in course of time provide

some measure of control over the periodic errors in right ascension of the FK3 system itself.

Until about 25 years ago, pendulum clocks of the regulator type were used as the standard clocks in observatories. A considerable improvement in precision was brought about by the invention of the free-pendulum clock. In an ordinary pendulum clock the timekeeping is impaired by the variable friction involved in driving a train of wheels to move the hands and record the actual time on a dial. An appreciably higher accuracy is to be expected if the pendulum is allowed to swing freely, except when it receives periodically impulses to maintain its swing, and is thereby relieved from all extraneous work. To achieve this had been the aim of horologists for many years, but although many attempts were made it was not really successfully accomplished until the invention by W. H. Shortt of his free-pendulum clock. The master pendulum is enclosed in an airtight case, in which the air pressure is reduced to about 1 inch of mercury and which is maintained at constant temperature and swings freely, except for small impulses, given at half-minute intervals, to maintain the amplitude at a nearly constant value. The slave clock is a normal synchronome electric clock, which is adjusted when swinging as an independent clock to lose about 6 seconds a day. The synchronizing action required from the master free pendulum is therefore a one-way action—always an accelerating action. The slave pendulum itself releases electrically the impulsing lever of the free pendulum, which falls when the free pendulum is at the midpoint of its swing. The impulse arm falls on the top of a small pivoted wheel, mounted on the free pendulum; this being a dead point, and the impulse not commencing to be given until the pendulum swings outward from the central position, the amount of the impulse does not depend upon any slight variation in the synchronization between the two pendulums which may occur.

The synchronization of the slave pendulum is effected by means of a light flexible spring carried on it. The impulse arm of the free pendulum, after it has fallen clear of the pendulum, actuates a device which closes an electric circuit and sends a current through a small electromagnet adjacent to the slave pendulum. If the slave clock has dropped sufficiently behind the master, the armature of this electromagnet will, when the electromagnet is excited, engage the bent end of the light spring on the slave pendulum. The end of the spring is then held fixed and, as the pendulum swings, the spring is flexed and the pendulum is accelerated; if, on the other hand, the slave pendulum is closely in phase with the master, the end of the spring passes under the armature before the electromagnet is excited, and nothing happens. The length and strength of the spring are so adjusted that when the synchronizing action occurs the slave pendulum is accelerated by

$\frac{1}{40}$ second. As the natural losing rate of the slave clock, 6 seconds a day, is equivalent to $\frac{1}{480}$ second per minute, the synchronizer, which is actuated each half minute, should hit and miss alternately. For this reason it is called the "hit-and-miss" synchronizer.

The first experimental Shortt free-pendulum clock was installed at the Edinburgh Observatory in 1921. It at once proved to be such an improvement upon previous pendulum clocks that two were installed at the Greenwich Observatory in 1923 and others in subsequent years. It was the excellent performance given by these clocks that made it necessary for astronomers for the first time to introduce the conception of mean sidereal time. Previously true sidereal time had been universally used, as clocks were not good enough to be able to show up the small effects due to the short-period terms in nutation. The free-pendulum type of clock is capable of an accuracy of about one-hundredth of a second a day. Detailed investigation of their performance has shown, however, that such clocks are liable to frequent small erratic changes of rate, of the order of about 3 milli-seconds a day. Small though such changes are, they cause, by integration, an irregular wandering of the clock. For sending out time signals, it is always necessary to extrapolate beyond the latest time determination; these erratic changes of rate restrict the accuracy with which the error of the clock can be extrapolated. It can, on occasion, happen that 2 weeks or more may elapse without any check on the performance of the clock being possible and the transmitted time signals may consequently be appreciably in error. Moreover, because of the errors of observation, there is a natural scatter in the derived errors of the clock. In interpolating between the observed errors there is no means of distinguishing between scatter due to errors of observation and scatter due to the irregular wandering of the clock. It is possible, of course, to attempt to reduce the effects of the wandering by using the mean of several clocks. Nevertheless, very high accuracy cannot be obtained, because residual effects due to the irregularities are always present.

A new standard of accuracy has been provided in recent years by the use of an oscillating quartz crystal, developed originally to serve as a precision standard of frequency. The quartz clock is based upon the piezoelectric property of quartz. If a plate of quartz is compressed, the two opposite faces become electrically charged, one positively and the other negatively. Conversely, if two opposite faces are given positive and negative charges respectively, the piece of quartz experiences a mechanical contraction or expansion. By rapidly alternating the electric charges, the quartz can be maintained in mechanical vibration. In the quartz clock an oscillating electrical circuit is used, the dimensions of the crystal being adjusted so that its

natural resonance frequency is equal to the frequency of the oscillating circuit. Under these conditions a strong vibration is set up and the quartz crystal takes control and locks the frequency of the oscillating electrical circuit to its own resonance frequency. Quartz is a very stable substance and, provided it is maintained at a very uniform temperature and the drive circuit is properly designed, the frequency remains constant to a high degree of accuracy. It is usual for the crystal to be cut to give a frequency of 100,000 cycles a mean time second, the dimensions of the quartz then being conveniently small. This frequency is divided down in steps electronically, either by the use of multivibrators or by frequency subdivision until an output with a frequency of 1,000 cycles a second is obtained. The output of this frequency is used to drive a phonic motor, from which time signals can be obtained at any desired intervals.

Such clocks have many advantages over pendulum clocks. They have proved to have very high short-period stability. Their erratic changes of rate are less than half a millisecond a day, and the clocks themselves can be relied upon to about 1 millisecond a day. For extrapolating between scattered time determinations they are therefore much superior to pendulum clocks. They have, moreover, the advantage of the great flexibility inherent in dealing with 100,000 vibrations a second instead of only a single one. Electronic methods can be used for quickly and accurately determining the relative errors and rates of the clocks. For such purposes at Greenwich, decimal counter chronometers are used. This device consists of a scale-of-ten counter, and is actuated by the 100,000-cycle output per second from one of the quartz crystals. When it is switched on, it will start counting these vibrations, recording the count on five decade dials, reading, respectively, tenths, hundredths, thousandths, ten-thousandths, and hundred-thousandths of a second. To compare two quartz clocks, a seconds signal from the phonic motor driven by the one clock is used to start the count and a signal from the second clock to stop it. The time difference between the two clocks, accurate to a hundred-thousandth of a second, is thus obtained in a fraction of a second. As a check, the second clock can be used to start the count and the first clock to stop it. The difference in frequency of the two clocks is obtained by feeding the 100,000 c. p. s. outputs from the two clocks into a comparator, so that they beat against one another, and timing the beats. It is possible to obtain an accuracy of one part in 10^{10} in the measurement of the frequency difference.

At Greenwich, the clocks are used in groups of three, one phonic motor being provided for each group of three clocks. One of the clocks is selected to drive the phonic motor, but regular comparisons are made between each pair of clocks in the group. Automatic beat

counters record the integrated time difference between each pair, A-B, B-C, C-A, the third comparison providing a check on the other two.

A further convenience of the quartz clocks is that it is not necessary to maintain separate mean-time and sidereal-time clocks as it is with pendulum clocks. By means of suitable gearing, it is possible to take sidereal seconds direct from the phonic motor which gives also mean time seconds. The ratio of the mean time second to the sidereal time second is 1.002 737 909 293. This ratio can be closely represented by a gearing of 119/114 multiplied by 317/330, which is only 4 parts in 10^9 small. These sidereal second signals are used for recording on the chronograph during the time determinations. When the rate of the clock relative to these signals has been derived it is a simple matter to infer its rate relative to true mean time seconds. The small error in the conversion from mean time to sidereal time is, of course, eliminated.

For short-period prediction quartz clocks leave little to be desired. They have not as yet, however, reached the stage at which long-period prediction has the accuracy that is desirable. The difficulty arises from a slow drift in frequency to which they are all liable. The crystal, after cutting, appears to go through a slow ageing process; the drift in frequency is rather rapid at first, but progressively diminishes though it seems never to cease altogether. If for any reason the crystal should stop, through a tube or resistor giving out, it will not, when restarted, follow along its previous ageing curve; a new ageing cycle sets in. Any small disturbance, such as a slight temperature change, can alter the frequency drift somewhat. The effect of the frequency drift on the error of the clock increases with the square of the time so that, even though the drift may be quite small, its effects will become important with lapse of time. With the present scatter in the actual time determinations, several months' observations are needed to give a sufficiently accurate derivation of the frequency drift, but there is always the uncertainty whether during this period some small disturbance may not have caused the rate of drift to change slightly.

Moreover there are extraneous effects which can complicate the determination. During a period of several months, there will be a wide range in the right ascensions of the stars which are used for the time determinations. If there are periodic errors in the fundamental system of star places, a spurious factor will have entered into the determination of the frequency drift. The motions of the earth's poles cause further complications. The poles have an irregular motion, which is roughly circular, but with a variable radius. The extreme departures of the true poles from their mean positions are about 30 feet. The movement of the pole along the meridian causes

a variation in latitude, which can be observed with a zenith telescope. The movement in the perpendicular direction causes a displacement of the meridian. The motion of the pole has two main components, with periods of a year and of about 14 months respectively. As a consequence of this motion, it would be found that if we had a perfect clock, with no rate at all, and observations which were entirely free from error, the clock would appear to have a slightly variable rate. This apparent variation of rate will affect the determination of the frequency drift and give a spurious value.

It is not possible at an observatory to measure the component of the polar motion at right angles to the meridian. At Greenwich an approximate compensation for the motion is made through the cooperation of the Naval Observatory, Washington, which sends regularly to Greenwich the observed movement of the pole along the meridian of Washington. If Washington were 90° in longitude west of Greenwich, the displacement along the meridian of Washington would also be the displacement at right angles to the meridian of Greenwich. But the longitude of Washington is only 77° west of Greenwich. However, the use of the Washington latitude-variation data does enable the greater part of the polar-motion effect to be eliminated from the Greenwich clock curves and it has been noticeable that the inferred performance of the clocks has thereby been improved.

The development of an atomic or molecular clock, in which the frequency of some selected atomic or molecular vibration will be subdivided to give a frequency closely equal to that of an oscillating quartz crystal and used to lock the vibrations of the crystal, is already foreshadowed by the work in progress at the National Bureau of Standards, Washington, in the development of an ammonia clock, in which the frequency of one particular mode of vibration of the ammonia molecule is used as the control. This work is as yet in its early stages and has not gone beyond the point of showing that the control of a quartz crystal in the way suggested is practicable. When the clock has been developed to the stage at which the accurate control of a precision quartz clock becomes possible, the crystal will be prevented from drifting in frequency. The clock error curve over a long period of time should then be represented by a straight line. Departures from a straight line could be attributed to periodic errors in the star places, to the polar motion, or to irregularities in the rate of rotation of the earth itself. Much more accurate long-term prediction would become possible, with a considerable gain in the accuracy of timekeeping.

It has been well established that the length of the day is subject to small fluctuations. It has long been known that there are discordances between the observed and the tabular positions of the moon which are not attributable to imperfections in the theory of the

motion of the moon. In the development of the theory, the gravitational effects which have been neglected are far too small to amount to anything like the discordances which are observed. In more recent years it has been proved that there are similar fluctuations in the motions of Mercury, Venus, and the sun; but for these bodies the effects are much smaller than for the moon because their mean motions are much less rapid. It was the comparative smallness of the effects for these bodies which made their detection difficult. So there are, in effect, four clocks which agree together and one clock, our earth, which differs from the other four. The natural conclusion is that it is the earth which is at fault and that the length of the day, which has been adopted as the unit of time and assumed to be invariable, is actually subject to small variations.

The changes in the length of the day are found, from the analysis of the observational data, to be of two different kinds. There is a slow progressive increase in length, of the order of 1 millisecond in the length of the day in the course of a century. This progressive increase is caused by tidal friction, more particularly in the shallow sea; it acts as a brake on the earth. Though so small in amount, the effect on the mean longitudes of the moon and the planets increases with the square of the time and is large enough to make the position of the moon 20 centuries ago, if computed from its present motion in longitude, very considerably in error. The effect was actually first detected in 1679 by Halley from the early observations of eclipses. Superposed on the progressive increase of length there are also irregular changes, the day sometimes increasing in length and sometimes decreasing; these changes cannot be attributed to tidal friction, because frictional effects can cause only a slowing down and never a speeding up in the earth's rotation. These changes are due to changes in the earth's moment of inertia and could be accounted for quantitatively if the earth expanded or contracted slightly by 4 or 5 inches.

There is one essential difference between the two phenomena. A change in the moment of inertia of the earth is something that concerns the earth alone. The apparent displacements of all the other bodies are strictly proportional to their mean motions. But tidal friction is something that concerns the earth and the moon jointly; the total angular momentum of the earth-moon system is conserved, but there is interaction between the earth and the moon. The apparent displacements of Mercury, Venus, and the sun will again be proportional to their mean motions but the same will not hold for the moon; its displacement will not have the same ratio to its mean motion. It is this difference in the case of the moon which makes it possible to separate the two effects of tidal friction and of change of the moment of inertia of the earth.

Though the changes in the length of the day have been fully established by these observations, the data are not sufficiently accurate to decide whether the changes occur suddenly or whether they are spread over a few days, a few weeks, a few months, or even over a year or two. If they occur rather suddenly, they could be detected with ease by quartz clocks in their present stage of development; if spread over a few months, the larger changes could be detected, but changes of smaller amount would be likely to escape detection. Since a few years ago, when quartz clocks were adopted at Greenwich as the basis for the time service, a close watch has been kept for any evidence of a change in the earth's rotation. Once or twice small changes have been suspected but there has always been some factor which has made a definite conclusion impossible—perhaps one of the clocks has changed its rate or has stopped at the crucial time, or there has been some uncertainty in the determination of frequency drift. The evidence provided by the observations of occultations of stars by the moon is that there has been no major change in the earth's rate of rotation since about 1918. There may possibly have been small changes, but no definite conclusions are as yet possible.

It is not inconceivable that there may be small annual variations in the rate of rotation of the earth. There are seasonal displacements of matter over the earth's surface; there is, for instance, a high-pressure region over Siberia at one season of the year and a low-pressure region at another season, entailing the displacement of large atmospheric masses, with corresponding change in the moment of inertia. Such effects would be tangled up with effects due to periodic errors in star places and with the effects of the polar motion. Much more is likely to be learned about these matters when the atomic clock has reached a further stage of development, so that the frequency drift of the quartz crystal can be eliminated. Observations with photographic zenith telescopes should gradually smooth out any residual periodic errors in star places, while the information they provide about the variation of latitude will furnish basic data which can be used subsequently to separate polar motion effects from small variations in the earth's rotation. It may prove, however, that the earth itself is rather like a pendulum clock in its behavior and that its rate of rotation is liable to frequent and small irregular changes, so that we can at present merely observe their integrated effect.

The question may arise in the near future how the unit of time should be defined. Clocks are now at a stage when their stability for short periods is of a higher accuracy than the earth's rotation itself. The earth, however, has the advantage over any clock that it has no liability to a stoppage. It may be possible to develop atomic clocks to a stage at which they can be run for several years

without stopping and to maintain accurate time; with a battery of such clocks, all controlled by the same atomic vibration, it would be possible to bridge over the stoppage of any single clock and thereby to maintain an accurate standard of time more or less indefinitely. There will be definite objections to using as the fundamental unit of time a unit that is known to be variable. A new unit should be absolutely invariable. A clock based fundamentally upon a length which is controlled by an atomic wave length, and upon the velocity of light, for instance, seems theoretically ideal.

NOTE 'ADDED IN PROOF.—Since the [lecture was delivered, investigations at the Greenwich Observatory have established the existence of a fairly regular annual variation in the rate of rotation of the earth. Relative to uniform time the earth gets behind by about 60 milliseconds in May–June and ahead by a similar amount in November. The corresponding variations in the length of the day amount to somewhat more than 1 millisecond a day on either side of the mean value. H. S. J.

THE ELEMENTARY PARTICLES OF PHYSICS¹

BY CARL D. ANDERSON

California Institute of Technology, Pasadena

The idea of elementary particles of matter, of small, discrete, indivisible particles out of which all matter in the universe is constituted, is as old as recorded history. The Greeks in their philosophical speculations discussed at length the question of the ultimate nature of matter. They realized that there were only two possible choices open to them; either matter must be thought capable of being divided into smaller and smaller units without end, or else it must consist of small units which are themselves wholly indivisible. Many of the Greek philosophers experienced a philosophical difficulty in trying to conceive of infinite divisibility, whereas others found it equally difficult to think of a particle as being truly indivisible. The difficulty is closely akin to that which one experiences when contemplating the limits of the universe, and trying to decide in his own mind whether it pleases him more to think of the universe as unbounded and extending to infinity, or to imagine a finite universe with definite bounds beyond which there is nothing, not even space. The idea of the existence of indivisible material particles, however, seems to have had more appeal to the Greeks, and the atomic hypothesis was expounded and developed in the fifth century B. C., chiefly by Thales, Leucippus, and his distinguished pupil, Democritus, until in many respects it resembled the views which are held today.

The views of Democritus were prominent for 500 years but began to wane after the beginning of the Christian Era and by about A.D. 200 had almost wholly disappeared from European philosophical thought. The idea of material atoms did not really appear again in Europe until about the middle of the seventeenth century, a time marking the beginning of the great era of scientific experimentation which has continued with an ever increasing tempo up to the present.

During this period, through scientific research based on experimentation, the atomic theory of matter slowly developed. Highlights in

¹ Based on material presented in the Sigma XI Annual Address, A. A. A. S. Centennial, Washington, September 1948. Reprinted from *American Scientist*, vol. 17, No. 2, April 1949, by permission from The Society of the Sigma XI.

this development were the Laws of Chemical Proportion as discovered and enunciated by Dalton near the beginning of the nineteenth century, and later the successes of the Kinetic Theory of Gases. By the beginning of the twentieth century, the concept of the chemical atom had received general acceptance as a theory based on scientific experimentation. The idea of atoms had thus been removed from the realm of philosophical speculation and had become a proved scientific fact. According to this picture all matter depending upon its nature consists of a mixture of varying numbers of the ninety-odd different chemical atoms. The size and the mass and other properties of most of the chemical atoms had been determined although not with great precision.

DISCOVERY OF FIRST ELEMENTARY PARTICLES

During the time when the chemical atom was being firmly established as a scientific fact, other scientific investigations were succeeding in proving the existence of at least one particle of matter which was more elementary in character than the chemical atoms. In the decade from 1890 to 1900 the discovery of X-rays and radioactivity, and studies of the phenomena associated with the discharge of electricity through gases, soon proved the existence of the *electron* and showed that the atoms of chemistry must all be considered as complex structures, structures which are themselves built up of particles of a more elementary character.

The electron was distinguished from the other particles previously studied by physicists and chemists in one very important respect. It was established as a unique particle in the sense that all electrons were found to be identical with one another, no matter from what form of matter they were derived. For the first time then the presence of a particle truly elementary in character was revealed to science. It was found always to carry a negative electric charge and to have a mass about 2,000 times less than the hydrogen atom, the simplest and least massive of all the chemical atoms. The electron immediately took its place as one of the elementary particles common to all forms of matter.

The following 30 years, from 1900 to 1930, were extremely fruitful in furthering our knowledge of the properties of the chemical atoms. The work of Moseley showed that chemical atoms were members of a family, all of them being related to one another in a perfectly definite and simple way. In 1911 the experimental genius of Rutherford in Cambridge, England, proved the existence of the atomic nucleus, and in 1919 he succeeded for the first time in producing an atom of oxygen from the disruption of the nucleus of an atom of nitrogen. Thus in 1919 the will of man for the first time was able to cause the disintegration of an ordinarily stable element, with the accompanying release

of nuclear energy. These and other investigations all combined to prove that the *proton*, the nucleus of the simplest of all the chemical atoms, hydrogen, is a constituent of all other chemical atoms, and hence is in fact one of the elementary particles of matter.

In 1930, then, the physicist had at his disposal two elementary material particles, the electron and the proton, in terms of which to try to understand the structure of all matter. In this undertaking the physicist realized many great successes, but in many instances his efforts resulted in sharp failures. Apparently the world was not to be understood in terms as simple as these.

In general the physicist was successful in understanding those phenomena which we may classify, for want of a better term, as extranuclear phenomena, and he was unsuccessful in understanding those phenomena which we may classify as nuclear phenomena. By extranuclear phenomena we mean those processes in which the electrons which form the outer shells of the atom are the active participating agents; in this type of phenomena the central core of the atom, or the nucleus, is present but remains undisturbed and does not participate actively. Nuclear phenomena, on the other hand, are those in which the nucleus is the active participant.

Extranuclear phenomena and nuclear phenomena have a great many distinguishing characteristics. One of the most interesting and important of these distinguishing characteristics is concerned with the level of energies involved. Extranuclear phenomena involve very low energies as compared with nuclear phenomena. The physicist uses the term *electron volt* as a measure of energy. The energies of extranuclear phenomena are found usually to range from a fraction of one electron volt to several electron volts, whereas nuclear phenomena are found usually to correspond to several millions of electron volts.

In our environment almost every phenomenon in nature represents an extranuclear phenomenon: for example, the burning of coal, the growth of plants, the generation of electric power by conventional means, the fermentation of wine, the explosion of dynamite, and others in uncountable numbers. Nuclear phenomena are not so commonplace, but a few examples may be mentioned: for example, the generation of the sun's heat, the decay of radium, the manufacture of plutonium, the absorption of cosmic rays in the earth's atmosphere, the explosion of an atom bomb.

The concept of energy has been introduced here because of the great importance that this concept has in the discussion of any physical phenomenon. I have stated that extranuclear phenomena represent low-energy phenomena and nuclear phenomena represent high-energy phenomena. To be more accurate I should have said that in extranuclear phenomena we find low *concentrations* of energy; that is, the energy changes that one associates with a single elementary particle

are low in extranuclear phenomena and high in the case of nuclear phenomena. Moreover, physicists for the past several years have been studying certain phenomena which represent energy concentrations many thousands of times greater than those represented even by nuclear phenomena. This range of energies has been called the range of *ludicrously* high energies. So far the only opportunity the physicist has had to study phenomena in the range of ludicrously high energies is in connection with observations associated with cosmic rays, and we shall see in a moment that important knowledge of the elementary particles of matter has come from studies of phenomena in the range of ludicrously high energies.

As stated previously, by 1930 two elementary particles of matter were known to the physicist, the electron which always occurred with a negative electric charge and the proton which always occurred with a positive charge. When considered in a manner consistent with the theoretical concepts as they had been developed up to that time in terms of the quantum mechanics, the negative electron and the positive proton served quite successfully as building blocks in terms of which to understand the structure of atoms so far as the extranuclear phenomena were concerned. But when attempts were made to picture the structure of the nuclei of the various chemical atoms, or to understand nuclear phenomena, the attempts usually ended in failure.

Then suddenly in 1932 two new elementary particles were discovered: the *neutron* and the positive electron, or *positron*. The known elementary particles were therefore doubled in number, increasing from two to four, and providing the physicist with more material with which to work.

The discovery of the neutron, which came as a result of experiments performed in Germany, in France, and in England, was immediately welcomed, for now neutrons together with protons could serve as the building stones for the various types of atomic nuclei. One very grave and fundamental problem which formerly had been present was now removed immediately, for it was no longer necessary to assume the existence of electrons *inside* the nucleus, a concept which always had been accompanied by serious theoretical difficulties.

The discovery of the positive electron, or positron, came during a series of experiments being performed for the purpose of measuring the energies of the particles produced by cosmic rays. The discovery of the positron was an unexpected discovery. This statement is true even though, about 2 years before, a British physicist, Dirac, had announced a new theory which actually predicted the existence of positrons. This new feature of physical theory was not welcomed by physicists, however; it was on the contrary considered to be an unfortunate defect in the theory, and many attempts, by Dirac himself

and others, were made to remove it, although all were unsuccessful. If even one physicist in the world had taken the theory of Dirac seriously, he would have had an admirable guide leading directly to the discovery of the positron. Had this happened, the positron would almost certainly have been discovered by 1930 rather than in 1932. However, after the positron was shown actually to exist, then it was a very short time indeed until many of its properties were understood in terms of the Dirac theory.

ELEMENTARY PARTICLES AND RADIATION

The discovery of the positron represented the first instance in which it was recognized that an elementary particle of matter may have only a transitory existence. In ordinary matter, for example, the average life span of a positron is only a few billionths of a second, for when a positron and a negative electron come close to one another they mutually annihilate one another—the two particles disappear and in their place one finds only radiation. The whole of the material substance constituting the particles is spontaneously transformed into radiant energy. Measurements show that this process is quantitatively in accord with the now famous Einstein equation $E=mc^2$, which relates mass and energy. The process which is the inverse of the annihilation of material particles also occurs, namely, the production of particles out of radiation. If radiation of sufficiently high energy is passed through matter, electrons and positrons are generated. In this process the material substance of the two particles is actually created out of the energy represented by the radiation, and again in conformity with the Einstein equation $E=mc^2$.

In the light of these happenings one must change basically his concept of the elementary particles of matter; these particles are no longer to be thought of as permanent objects which always preserve their identity, and which serve only as building blocks of matter by joining together in groups to form the more complex chemical atoms. One must recognize instead the possibility of the creation of material particles out of radiation, and the annihilation of material particles through the production of radiation. Such a possibility as this, of course, was completely inconceivable to the Greeks in their long philosophical discussion on the indivisibility of matter versus the divisibility of matter.

A further step toward a realization of the great complexity inherent in the relationships among the elementary particles of matter came in 1935 with the discovery of the *positive* and *negative mesotrons*, or *positive* and *negative mesons* as they are now often called. This discovery was also made in investigations of the high-energy phenomena occurring when cosmic rays are absorbed in their passage through matter.

The mesotron is a particle some 200 times as massive as an electron, and therefore about one-tenth as massive as either a proton or neutron. It occurs with both positive and negative electric charge. The discovery of the mesotron did not come quickly and accidentally as was the case with the positron and the neutron. It came only after the completion of a sustained series of observations, covering a period of 4 years, which were designed to remove certain inconsistencies always present when we attempted to understand certain cosmic-ray phenomena in terms of the elementary particles then known. These inconsistencies were removed in terms of the existence of the mesotron, whose discovery was publicly announced in 1936.

Unlike the neutron, the mesotron was not a particle to be immediately welcomed by the physicist. The physicist makes his advances by simplifying his understanding of nature; hence, a physical world which could be explained in terms of only one or two distinct elementary particles would be most to his liking. The discovery of the mesotron did not introduce a simplification; rather it complicated the situation for it increased the number of material elementary particles from four to six. Apparently the Creator does not favor a world of too great simplicity.

Before the discovery of the mesotron a Japanese physicist, Yukawa, had postulated on theoretical grounds the possible existence of particles of a mass intermediate between a proton and an electron. His theory, however, was not generally known to physicists at that time, and did not have any part at all in the discovery of the mesotron. Had this theory been generally known it is still doubtful if it would have affected the course of cosmic-ray research, since, unlike the Dirac theory of the positron, it would not have served as so useful a guide in pointing out the most fruitful directions for the research to follow.

Like the positron the mesotron has a very short life expectancy. In free space, both positive and negative mesotrons have a normal life span of just over two-millionths of a second, after which time they spontaneously disintegrate. Very recent observations have shown that in all probability the spontaneous disintegration of a mesotron results in the simultaneous production of an electron and two *neutrinos*. Neutrinos are the interesting elementary particles which had previously been invented in order to balance energy and momentum in the process in which an electron is produced when a radioactive nucleus decays. A similar situation exists in the case of the decay of a mesotron except that here, because the mesotron disappears entirely, it is necessary to postulate the emission of *two* neutrinos in order to balance energy and momentum.

In free space mesotrons spontaneously decay after about two-millionths of a second. In the presence of matter, a mesotron of

negative charge may terminate its existence in an even shorter time. It does this by entering an atomic nucleus or, in the language of the physicist, by undergoing nuclear capture.

The mesotrons observed in cosmic rays are produced by the very high energy particles of the primary cosmic-ray beam as it comes into the earth from outer space and plunges through the earth's atmosphere. In a manner somewhat analogous to the creation of positrons and electrons, the mesotrons are born out of the tremendous energies carried by the primary cosmic-ray beam.

There are many interesting phenomena involved in the birth and death of mesotrons and in the violent nuclear processes which accompany these phenomena, but it will not be possible to discuss them here. However, I should like to mention in this connection two important advances which have been made within the last 2 years.

RECENT ADVANCES IN NUCLEAR RESEARCH

One of these is the work under way in Bristol, England, by Powell and his coworkers, which has consisted of a detailed analysis of the tracks produced by mesotrons in the emulsions of photographic plates. These investigators have discovered a mesotron of a new type which is heavier than the ordinary mesotron. It is about 285 times as massive as an electron, whereas the ordinary mesotron is about 215 times as heavy. The heavy mesotron has only a very short life; it lives only about one one-hundredth as long as the light mesotron, after which time it disintegrates and produces a light-weight mesotron and another particle which is probably a neutrino. The negatively charged heavy-weight mesotron may also directly enter an atomic nucleus and give rise to a violent nuclear disruption.

Although both the newly discovered heavy mesotrons and the light mesotrons discovered in 1936 have some properties in common—e. g., both types of particles occur with positive and negative charges, both have short lives, and both are found in cosmic rays—nevertheless in some very fundamental respects they are entirely different types of elementary particles. The heavy mesotron interacts very strongly with atomic nuclei, but the light mesotron interacts only very weakly with atomic nuclei. Another difference lies in the respective values of that important property known as the spin or angular momentum; recent researches indicate that the heavy mesotron has an integral spin, whereas the light mesotron has a half-integral spin.

In all probability it is the heavy mesotron and not the light mesotron which is to be identified with the particle first postulated on theoretical grounds by Yukawa in 1934. The theory of Yukawa even in its present state today is very primitive. However, this theory still provides the best basic concept in terms of which to understand processes involving mesotrons, and after further development in the future the

Yukawa theory may possibly provide an understanding in terms of mesotron exchange forces of that all-important problem as to the nature of the forces acting between the particles inside a nucleus. So far no satisfactory theory has been developed in terms of which to understand many of even the simplest phenomena involving the nucleus. To acquire a quantitative understanding of the interactions of the elementary particles of matter and of the fundamental nuclear processes is one of the great tasks of theoretical physics today.

To complete our list of elementary particles we should also include the *photon*. This particle, together with the neutrino as noted above, is, however, in a somewhat different category from the other types of particles. The photon is not a material particle, in the sense that it cannot be identified with any particle which can exist at rest and have associated with it a finite amount of ponderable material substance. Photons are to be identified only with radiation or radiant energy. The neutrino must also be placed in a special category, since it cannot have associated with it an appreciable amount of ponderable material substance if any at all, and since it has never been directly observed.

In all, then, the physicist at the present time recognizes at least 10 distinct elementary particles of matter. Whether this list is complete or not no one can say with certainty. The indications are that the list is not complete, for evidence seems to be rapidly accumulating for the existence of at least one additional elementary particle. This particle is found in cosmic rays and appears to have a mass some 1,000 times the mass of the electron. But what its properties are and how it is related to the light and heavy mesotrons and to the other elementary particles of matter is a subject which must await the results of further observations.

The thought of probable further additions to the list of elementary particles of matter suggests a question which is quite apart from physics and has to do simply with the naming of new particles. We have here actually an interesting example of the great difficulties that physicists sometimes have merely in assigning labels or names to the various concepts which their experience or their theories have brought forth. It is usually necessary to choose some sort of name for these concepts, whether they be elementary particles of matter or something else, at a time before all the facts regarding them are known. In 1937 the term mesotron was suggested to designate the new particle of intermediate mass discovered in the cosmic rays in 1936. Since then this term has often been contracted to meson and has been so employed. Since the discovery of the new particle whose mass is greater than the mass of the original cosmic-ray mesotron, the term mesotron or meson has been employed to designate both types of particles and the Greek-letter prefixes π and μ used to differentiate between them.

Thus the term π -mesotron or π -meson designates the heavier particle and μ -mesotron or μ -meson designates the lighter particle. This nomenclature seemed satisfactory for a time until continued experimentation began to show more and more clearly the important basic differences between the two types of particles. It is beginning to be quite apparent now that the properties of these two types of particles are such that they will not naturally fall into the same classification. Thus the use of a common generic term, such as mesotron or meson, to designate both these types of particles may in the future prove to be quite inconvenient and illogical. Just what should be done with respect to nomenclature at this time is not clear, but it is a matter which should receive very serious consideration, especially in view of the apparent entry of still another new elementary particle into the fold.

Another important advance that I want to mention is the recent success in producing mesotrons in the large cyclotron on the University of California campus at Berkeley. This represents the first time that it has been possible by artificial or laboratory methods to imbue a single particle of matter with an energy sufficiently high to make possible the creation of mesotrons. This they have succeeded in doing in Berkeley with their beam of α -particles, or helium nuclei, which have been accelerated to an energy of 400 million electron volts. They observed the production of both the heavy and light mesotrons, and all indications are that the mesotrons thus produced are identical with those previously observed among the particles produced by the cosmic rays.

Now in the design stage are other particle-accelerating machines which will yield particle energies several times the 400 million electron volts so far achieved in the Berkeley cyclotron. When these machines are in operation, working at energies up to 6 or 7 billion electron volts, we can expect to learn much more about mesotrons and the other elementary particles of matter. Moreover, we must expect that a continuation of research in cosmic rays will also extend our knowledge in this field, since in the cosmic rays particles are available for study whose energies are even 10 to 100,000 times greater than those to be expected from any of the accelerators that are being planned.

In conclusion I should like to indicate the possible significance of these new discoveries to science and to the world at large.

In this discussion I have classified physical phenomena, according to the energy associated with them, into three categories: (1) low-energy or extranuclear phenomena, (2) high-energy or nuclear phenomena, and (3) extremely high-energy or what we might call, for want of a better name, elementary-particle phenomena. Knowledge of the first of these, low-energy or extranuclear phenomena, has already profoundly affected the life of nearly every human being on earth.

The industrial revolution, our mechanized civilization, the shrinking of the world through advances in communication and transportation have all come as a direct application of our knowledge of low-energy or extranuclear phenomena. Indirectly it has been responsible for the political and economic organization of the whole earth. Our present age might well be classified as an extranuclear age.

Since the explosion of the atomic bomb, and the achievement of the release of nuclear energy on a large scale, it seems rather clear that we are now entering a new period in which nuclear phenomena are destined to have an important part in shaping the world, at least politically if not economically, in the very near future. Just how great will be the influence on the world of our knowledge of nuclear phenomena no one can say.

It is only 50 years since our direct knowledge of the electron was not much more than a faint green glow in a glass tube—and now no one would deny that our knowledge of the properties of the electron has had an effect of profound importance in shaping our civilization. It is also only about 50 years since the world's knowledge of nuclear phenomena consisted of nothing more than the thoughts passing through the mind of Becquerel as he pondered a darkened area on a photographic plate. At present our knowledge of all these fields is incomplete, but particularly is this true of nuclear phenomena, and most particularly true of high-energy phenomena or the phenomena of the elementary particles.

So far, the world's knowledge of the phenomena of high energies or the interactions between the elementary particles is represented by nothing more than a few printed pages in the scientific journals, by discussions among physicists, or perhaps by an occasional lecture. But we can look forward with anticipation and even excitement to the new discoveries which are surely to come as studies are carried forward of elementary particles and very high-energy processes. New phenomena of great beauty, extreme complexity, and novelty are certain to be revealed and finally to be understood. Whether our knowledge of these new phenomena will then exert a great or a small influence on the world as a whole no one can say. I believe it would be most unwise, however, in the light of the history of scientific development, to expect this influence to be small.

RECENT ADVANCES IN VIRUS RESEARCH

By WENDELL M. STANLEY

*Professor of Biochemistry and Director of the Virus Laboratory
University of California*

Viruses are small infectious agents that can cause disease in man, other animals, plants and bacteria. They range in size from about 10 m μ , a size slightly smaller than that of certain protein molecules, in an almost continuous spectrum of sizes up to about 300 m μ , a size slightly larger than that of certain accepted living organisms. A given virus can multiply and cause disease only when within the cells of certain specific living organisms. No virus has been found to reproduce in the absence of living cells. During multiplication viruses occasionally change or mutate to form a new strain which in turn causes a new disease. Viruses were not discovered until 1892 when Iwanowski demonstrated that the causative agent of the mosaic disease of tobacco would pass through a filter that retained all known living organisms. Six years later Beijerinck proved that this agent was not an ordinary living organism and recognized it as a new type of infectious disease-producing agent—namely, a virus. The same year Loeffler and Frosch demonstrated that foot-and-mouth disease of cattle was caused by a virus. The discovery of the first virus disease of man, that of yellow fever, was made in 1901 by Reed and coworkers.

Since the original discovery of the infectious, disease-producing agent known as tobacco mosaic virus, well over 300 different viruses capable of causing disease in man, animals, and plants have been discovered. Among the virus-induced diseases of man are smallpox, yellow fever, dengue fever, poliomyelitis, certain types of encephalitis, measles, mumps, influenza, virus pneumonia, and the common cold. Virus diseases of animals include hog cholera, cattle plague, foot-and-mouth disease of cattle, swamp fever of horses, equine encephalitis, rabies, fowl pox, Newcastle disease of chickens, fowl paralysis, and certain benign as well as malignant tumors of rabbits and mice. Plant virus diseases include tobacco mosaic, peach yellows, aster yellows,

¹ Talk presented at the Medal Day Meeting at The Franklin Institute, October 20, 1948. Reprinted by permission from Journal of the Franklin Institute, vol. 246, No. 6, December 1948.

potato yellow dwarf, alfalfa mosaic, curly top of sugar beets, tomato spotted wilt, tomato bushy stunt, corn mosaic, cucumber mosaic, and sugarcane yellow stripe. Bacteriophages, which are agents capable of causing the lysis of bacteria, are now regarded as viruses.

The viruses have been separated as a special group of infectious, disease-producing agents by means of several general properties, no one of which is, however, exclusively characteristic of viruses. Nevertheless, no great amount of difficulty has been encountered in the segregation of the virus group. Viruses are characterized by their small size, by their ability to reproduce or multiply when within the living cells of a given host, by their ability to change or mutate during multiplication, and by their inability to reproduce or grow on artificial media or in the absence of specific living cells. The sole means of recognizing the existence of a virus is provided by the multiplication of the virus which is, of course, usually accompanied by manifestations of disease. Viruses spread from diseased to normal-susceptible hosts by different methods. Some are transferred by direct contact, as when a diseased leaf is caused to rub against a healthy leaf by a gust of wind, or when a normal person or animal comes into direct contact with a diseased person or animal. Such viruses can usually be spread by indirect contact through the medium of nonspecific animate or inanimate objects. Some viruses cannot be transferred by direct contact, but require an intermediate host such as a mosquito, louse, or leafhopper. In some cases a highly specific intermediate host is necessary, and a more or less definite period of incubation within this host may be required before the virus can be transmitted.

Because properties such as reproduction and mutation have long been considered characteristic of living entities, viruses were, for many years, regarded as living organisms somewhat smaller than ordinary bacteria. However, the isolation in 1935 of tobacco mosaic virus in the form of a crystalline nucleoprotein of unusually high molecular weight and the subsequent isolation of still other viruses in the form of high molecular weight nucleoproteins, some of which were also crystallizable, cast doubt upon the validity of classifying all viruses as organisms. With the exception of virus activity, the properties of some of the smaller viruses are quite similar to the properties of ordinary protein molecules, whereas at the other extreme with respect to size, the properties of the viruses are more nearly like those of accepted living organisms. The viruses, therefore, serve as a bridge between the molecules of the chemist and the organisms of the bacteriologist, and provide us with new reasons for considering that life, as we know it, owes its existence to structure, to a specific state of matter, and that the vital phenomenon does not occur spontaneously, but is possessed in varying degrees by all matter. It is

obvious that a sharp line dividing living from nonliving things cannot be drawn and this fact serves to add fuel for discussion of the age-old question "What is life?"

Attempts to learn something about the nature of viruses through studies on their general properties began with Beijerinck's work in 1898 and were continued in different laboratories for over 30 years without too much success. Although Beijerinck and Allard made important contributions, perhaps the most significant work was that of Vinson and Petre during the years from 1927 to 1931 when they showed that tobacco mosaic virus could be subjected to several kinds of chemical manipulations without loss of virus activity. Nevertheless, in 1932 the true nature of viruses was a complete mystery. It was not known whether they were inorganic, carbohydrate, hydrocarbon, lipid, protein, or organismal in nature. It became necessary, therefore, to conduct experiments which would yield information of a definite nature. Tobacco mosaic virus was selected for these initial experiments because it appeared to provide several unusual advantages. Large amounts of highly infectious starting material were readily available and the virus was known to be unusually stable. Furthermore, it was possible to titrate or measure the amount of this virus in a preparation with ease and rapidity and with great accuracy. During the course of a wide variety of early exploratory experiments, it was found that the enzyme pepsin inactivated tobacco mosaic virus only under conditions under which pepsin is active as a proteolytic agent. It was concluded that tobacco mosaic virus was a protein or very closely associated with a protein which could be hydrolyzed by pepsin. With this as a lead, efforts were made to concentrate and purify tobacco mosaic virus by means of the methods previously employed in work with proteins. Soon, by means of a combination of procedures involving salting-out, isoelectric precipitation and adsorption on and elution from an inert material, a crystalline material was obtained which possessed the properties of tobacco mosaic virus. This crystalline material was found to be a nucleoprotein with rod-shaped molecules or particles about 280 by 15 $m\mu$ in size and with a molecular weight of about 40,000,000. Early skepticism that a virus could exist in the form of a crystallizable nucleoprotein has largely disappeared, chiefly because the results of a vast amount of experimental work have indicated that the virus activity is a specific property of the rod-shaped nucleoprotein.

Tobacco mosaic virus exists in the form of many strains which appear to have arisen by a process similar to that of mutation in higher organisms. Several of these strains have been obtained in purified form by means of differential centrifugation. Purified preparations obtained from plants diseased with different strains of

tobacco mosaic virus were found to possess properties quite similar to, yet in every case distinctive from, those of purified preparations of the ordinary strain. Spectacular progress has been made in the establishment of the nature of the chemical changes which accompany the mutation of tobacco mosaic virus. The amino acid composition of purified preparations of eight strains of tobacco mosaic virus and of two types of influenza virus has been determined. The results obtained with the strains of tobacco mosaic virus indicate that the mutation of a virus can be accompanied by the elimination of one or more amino acids from the virus structure, by the introduction of one or more new amino acids into the virus structure, or by a change in the concentration of one or more amino acids present in the virus structure. This work has great significance for it has provided the first information regarding the nature of the structural changes which accompany mutation. Extension of this work may reveal the exact nature of the chemical differences between virulent and avirulent virus strains, and provide important information regarding the mutation process in higher organisms.

Attempts have been made to change the structure of tobacco mosaic virus by means of known chemical reactions *in vitro* in an effort to secure chemically modified active virus. Although several types of chemical derivatives of this virus were produced and were found to possess full virus activity, the inoculation of such virus derivatives to normal Turkish tobacco plants always resulted in the production of ordinary tobacco mosaic virus. The results indicated that the chemical derivatives were converted to ordinary virus following their introduction into the cells of the plant, or, more probably, that the infecting molecules may not necessarily function as exact patterns for reproduction. Despite these results it still appears that it may be possible to make changes *in vitro* similar to those which occur in nature, and thus secure a heritable chemical modification. Obviously this is a field in which important new results can be anticipated.

Following the isolation of tobacco mosaic virus in the form of a crystalline nucleoprotein having individual molecules or particles about 15 by 280 $m\mu$ in size, studies were undertaken in several laboratories to determine if other viruses could be obtained in purified form, mainly by techniques involving high-speed centrifugation. Some of these purified viruses are crystallizable nucleoproteins having either rodlike or spherical particles. Some are nucleoproteins which have, as yet, not been crystallized. Others are large particles consisting of nucleoprotein, lipid, and carbohydrate, and possessing, in some cases, a degree of morphological differentiation which resembles that of organisms. Still other viruses have, as yet, defied isolation and purification, possibly, in some cases, because of extreme instability. The viruses

which have been purified possess varied shapes and form an almost continuous spectrum of sizes. The smaller rod or spherically shaped viruses appear to be simple nucleoproteins, some of which can be obtained in crystalline form. These appear to have chemical and physical properties which, neglecting virus activity, would tend to place them in the molecular world. The larger viruses have a composition and properties which are characteristic, not of molecules, but of organisms. The viruses have certainly provided a link between the molecules of the chemist and the organisms of the biologist. Yet there is no place at which a line can be drawn dividing the molecules from the organisms.

The viruses appear to form a continuous series with respect to structure, ranging from the smaller viruses, which are simple nucleoproteins with many properties similar to those of ordinary molecules, on through viruses with a gradually increasing complexity of structure, to the larger viruses, which, with respect to structure and properties, are similar in many respects to organisms. However, it must be remembered that the properties of only a relatively few purified viruses have been determined. In view of the possibility that these represent the more stable and more easily purified viruses, one cannot be certain that a true picture of the chemical and physical properties of viruses as a whole has been obtained as yet. Information regarding the mode of reproduction of viruses is needed most urgently. At present it is not known whether viruses reproduce by fission or by means of some new process. The solution of this puzzle would certainly represent a most important and significant advance, for the basic reactions characteristic of virus reproduction may well represent the fundamental process which characterizes all living things.

GROUND-WATER INVESTIGATIONS IN THE UNITED STATES ¹

BY A. N. SAYRE

*Geologist in Charge, Ground Water Branch
Water Resources Division, U. S. Geological Survey*

Before discussing ground-water investigations in the United States I should like to outline briefly the broad problems of water supply, water control, and conservation, in the solution of which ground-water investigations play an important part.

For mere existence, a man requires only about 2 quarts of water per day. However, even in simple pastoral or agricultural settings, the biological necessity represents only a part of the total needs for water, and in our own complex industrial and agricultural economy great quantities of water are needed for a multitude of purposes. Water is needed for sanitation, for washing clothes, for facilitating sewage disposal, for scrubbing floors, and for processing foods. It is needed for fire protection, for generating power, and for industrial processes, for irrigation, for air conditioning, and even for producing atomic energy. The task of providing water at the right time and place is a serious problem which fully occupies the attention of thousands of engineers and chemists and a smaller number of geologists. Intimately associated with the water-supply problem is the problem of controlling floods to minimize the erosion of our soils and to conserve floodwater for beneficial uses. For obvious reasons, many of our agricultural, industrial, and urban developments have taken place along waterways where they are vulnerable to the ravages of floods which appear to become more costly almost year by year. There is good reason to believe that the demand for water supply will continue to increase and that the demand for control and conservation of floodwaters will also increase. Projects for accomplishing these ends will become more expensive and their planning and design will require greater knowledge of our water resources and of the basic geologic and hydrologic factors affecting them.

¹ Presented at the joint meeting of the Society of Economic Geologists and Geological Society of America, Ottawa, Canada, December 1947. Reprinted by permission from *Economic Geology*, vol. 43, No. 7, November 1948.

Especially during the past century, the use of water has increased at an amazing rate. In 1850 only 83 cities in the United States had public water supplies, and only a small proportion of the homes in these cities had water piped directly from the city mains. By 1939 there were 12,760 ² municipal waterworks and thousands of industries had private supplies from wells or surface-water sources. As the number of waterworks increased, the uses of water and the per-capita consumption also increased. The quantities of water used for a few purposes are given below. Flush toilets, bathing and laundry, street cleaning, and fire protection require an average of about 40 to 75 gallons per day per capita.³ Processing a ton of steel in highly finished form requires about 65,000 gallons ⁴ of water; making a gallon of gasoline takes 7 to 10 gallons ⁵ of water. Vast quantities of water are used for air conditioning and for making paper, explosives, coke, textiles, and a host of other products. Thus, a large city, such as Chicago, with numerous industries may have a per-capita water consumption as high as 250 to 300 gallons per day.

Only a few thousand acres in the West was irrigated [in 1850, but 21 million acres ⁶ was irrigated in 1939, and many additional irrigation projects are under construction. An acre of cotton uses about 2.5 ⁷ acre-feet, or 800,000 gallons, of water during the growing season; an acre of alfalfa requires about 4 acre-feet of water; irrigation of truck gardens, fruits, sugarcane, rice, and other crops also requires large amounts of water. In eastern United States, supplemental irrigation is increasing because the application of a relatively small amount of water when it is needed by crops may double or triple the yield of the land.

The greatly increased use of water has, in many places, almost fully utilized the readily available water supplies, drawn ground-water levels dangerously low, caused sea water to enter streams and ground-water reservoirs in coastal areas, and permitted oil well brines or factory wastes to pollute many of our ground-water reservoirs and streams. Thus, the development of additional water supplies for new projects or industries has become increasingly difficult and costly. Nevertheless, it would be a mistake to infer that our water supplies are approaching exhaustion. Actually, much can be done to conserve and thereby increase the total amount of water available for beneficial use. For example, in many places spacing pumped wells over wider

¹ Engineering News-Record, vol. 123, p. 414, 1939.

² Turneaure, F. E., and Russell, H. L., Public water supplies, 4th ed., p. 19. John Wiley & Sons, New York, 1940.

³ Lloyd, Kenneth M., Industry and water supply in Ohio. Ohio State Univ. Exper. Stat. News, p. 31, April 1946.

⁴ Jordan, Harry E., Industrial requirements of water. Amer. Water Works Assoc. Journ., vol. 38, pp. 65-68, 1946.

⁵ Census Bureau.

⁶ National Resources Committee, Regional Planning, pt. 6, p. 91, 1938.

areas would prevent excessive lowering of the ground-water levels. Artificial recharge of ground-water reservoirs by spreading floodwaters and by other means has been successful in several areas. Abatement of pollution in streams and ground-water reservoirs, retention of floodwaters in reservoirs for later use, control of reservoir stages by forecasting normal and flood flows of streams, control of silt and sedimentation, and other measures are being carried out to increase the supply available for perennial beneficial use. The continued growth and prosperity of the Nation will depend to a large degree upon the success with which these problems are attacked and solved.

Unlike most mineral resources, water is not exhaustible, in the strict sense, because it is replenished from time to time by precipitation. A surface reservoir may be dangerously low and be refilled in the nick of time by heavy rains. Heavy pumping may cause ground-water levels to decline progressively until pumping is no longer economically feasible, but when pumping is temporarily or permanently reduced the water levels usually recover. Likewise, a period of heavy rainfall following a drought period may induce recharge sufficient to restore water levels essentially to predrought levels.

Only a part of the water taken from streams or pumped from wells is actually consumed. In many manufacturing processes water is merely a washing agent and is essentially unreduced in volume by its use. Water used in boilers or in quenching hot metal is partly evaporated, but the remainder is discharged or re-used. Water used in irrigation is partly evaporated and partly transpired by plants, but there is always an excess which is discharged and which carries away undesirable salts. The excess water from all these uses returns to the stream or to the ground altered by the concentration of minerals contained in it, or by the addition of dissolved constituents, or of color, or sediment, or simply by the addition of heat. It may be re-used for the same or other purposes with or without the addition of new water. For example, the water of the Pecos River, in Texas and New Mexico, is used and re-used for irrigation and domestic supply seven or eight times between its source and Girvin, Tex. Although water is added from tributary areas along its course, each time the water from the river is used the mineral concentration increases, and a few miles above Girvin it is so highly mineralized that even the most resistant crops are unable to survive its application. Even so, it may still have potential use, because water also possesses the energy of position and in its journey from the mountains to the sea it may be used many times over for generating hydroelectric power.

Another characteristic peculiar to water results largely from the vagaries of precipitation. Many places are faced successively with

water shortages and destructive floods. Although enormous sums have been spent on flood control, complete protection from floods is difficult and often prohibitively costly, and in only a few places has it been accomplished.

Whatever conclusions are reached with regard to the economics of flood control by storage reservoirs, from the standpoint of conservation of water supply it is advantageous to salvage as much of the floodwater as possible. In certain areas where water supply is now inadequate, as it is in many places west of the 100th meridian, much of the water from precipitation escapes to the sea during floods. In Los Angeles County, Calif., much of the floodwater is retained in surface reservoirs from which it is later discharged into specially prepared recharge basins and seeps into the underground aquifers. Some of the floodwater is caught in seepage reservoirs designed to promote infiltration into the ground-water basins, and some of it escapes to the sea, but essentially all the floodwater in the Los Angeles area will be put to beneficial use when the projects now under consideration are completed. Plans for similar flood control in other parts of the country are in various stages of execution.

Ground water and surface water are so intimately related that for proper solution of the over-all problems of water supply, control, and conservation it is now necessary to have all the facts regarding both. Precipitation, which is the source of both, is partly lost, largely through evaporation. Especially during the growing season, a large part enters the ground and is transpired by plants. The remainder percolates downward below the plant roots to become ground water, or runs off directly as surface flow. The ground water, returning to the surface as seeps or springs, provides the base flow of the streams which prevails through periods of low precipitation. On the other hand, especially in the West, many streams lose water by seepage in certain stretches and thus recharge the ground water reservoirs.

Many of the basic ground-water investigations in the United States are carried on cooperatively by the United States Geological Survey and State or local agencies, including State geological surveys, State engineers, counties, and municipalities. In Illinois ground-water investigations are made by the State Geological Survey and the State Water Survey; and in Missouri investigations are made by the State Geological Survey. In California a large staff of engineers in the State Division of Water Resources for many years has been investigating overdraft of ground-water supplies. Recently arrangements were made whereby the United States Geological Survey, in addition to its investigations in Los Angeles, Orange, and Santa Barbara Counties, will assist the Division of Water Resources in the geological phases of a State-wide inventory of the water resources of California.

Various other Federal and State agencies are obtaining some data on ground water in connection with special phases of their work.

The ground-water investigations of the United States Geological Survey began more than 50 years ago. At that time ground-water supplies were little developed. Consequently, most of the early field investigations were of the exploratory type. Laboratory and field studies by King, Slichter, and later by Meinzer outlined the broad principles of ground-water occurrence and movement. However, before the deep-well turbine pump was developed in the early part of this century, use of ground water in large quantities was limited to areas of springs or artesian flow, or to areas where the water level was within reach of suction pumps. After the turbine pump was introduced, it became possible to pump economically even where water levels are deep; power costs also decreased, and well drilling and finishing methods were improved to increase the efficiency of wells. Because of these advances, ground water came to be used in ever-increasing quantities, first in areas where surface water was not readily available, and later in areas where ground-water supplies were more economical because they obviated the long pipe lines, collection works, and costly treating plants needed for surface-water supplies. The first great expansion of ground-water supplies was made largely without technical guidance. Because of their immense storage capacity, the ground-water reservoirs were regarded as inexhaustible, and in many places development was well advanced before progressively declining water levels brought about the realization that ground-water reservoirs may be depleted. As a result, demands for detailed ground-water studies steadily increased. These studies are thorough, systematic investigations which include areal geologic mapping; subsurface studies occasionally augmented by geophysical surveys and test drilling to determine the structure, thickness, and the sequence of water-bearing and non-water-bearing beds; collecting data on fluctuations of water levels in relation to precipitation and to pumpage; determining the recharge and perennial yield; inventories of ground-water withdrawal; test pumping to determine coefficients of permeability, transmissibility, and storage; determining the quality and temperature relationships, and the relations between surface and ground water. The work does not include supervision, construction, or control of water supplies.

The United States Geological Survey is now making cooperative ground-water investigations in 42 States and in Alaska, Hawaii, the Virgin Islands, and Puerto Rico. In general, the State or local authorities are most familiar with the needs in their States, and they are largely responsible for designating the areas in which investigations are to be made. Most of the ground-water staff of the United States Geological Survey now have headquarters in field offices, of which there are about 40.

In addition to the cooperative investigations with States and local agencies, certain investigations primarily of Federal interest are being carried out with use of Federal funds only. For example, an extensive program of ground-water investigations is being conducted in the Missouri River Basin to provide basic information needed for planning and constructing the various water projects that are authorized or planned. This information will include determination of existing ground-water conditions and probable effect of irrigation on ground-water levels, especially with reference to waterlogging and drainage, canal locations with reference to seepage, areas where irrigation with ground water is feasible, the location of potential sources for farmstead and municipal water supplies, and so on. Other investigations, such as that recently started in the Central Valley of California, will provide basic information needed in the project to use excess floodwaters for recharging the heavily pumped ground-water reservoirs in the San Joaquin portion of the valley. Several projects also are under way in connection with defense plans.

A large program of measurement of ground-water levels in observation wells has long been an integral part of the cooperative program. Recently a small Federal fund was provided for extending this program, analyzing the data, and determining the current status of our ground-water supplies on a Nation-wide scale. The program includes the investigation of the possibilities of forecasting low-stage stream flows from fluctuations of ground-water levels, enabling more efficient control of reservoir and river stages in the operation of hydroelectric plants and permitting considerable economies in the generation of power. Conversely, base flow is an index of ground-water storage. As the ability of the ground-water reservoirs to absorb water materially affects the runoff to be expected from rainfall, the analysis of data on ground-water levels should aid in flood forecasting.

In addition to and as part of the above program, several research projects are under way, including the study of movement of water through soils and water-bearing materials; infiltration from streams and its effect on the temperature and quality of the ground water; the occurrence of ground water in fractures and solutional openings in impermeable rocks, such as limestone, tightly cemented sandstone, granite, etc., and the improvement of our techniques for locating producing wells in such rocks; earth subsidence resulting from the withdrawal of ground water, and related problems connected with elasticity and compressibility of artesian aquifers; methods of analyzing results of pumping tests to determine coefficients of transmissibility and storage; and a number of other projects.

With respect to the probable future of ground-water investigations, it should be pointed out that ground-water development was expand-

ing rapidly in the middle thirties. In 1935 the total use of ground water in the United States amounted to about 10 billion gallons a day. The development was greatly accelerated by the needs of the war, so that by 1945 the total pumpage had nearly doubled.⁸ Although the war ended more than 2 years ago there has been no sign of a decrease in the use of ground water. In fact, both surface water and ground water are now being used in greater quantities than ever before. As the use of water approaches ever more closely the limits of the available supply, it is believed that water-resources investigations will be needed with ever-increasing urgency because water constitutes the prime factor in the continued development of the Nation's industrial and agricultural economy.

⁸ Guyton, W. F., Industrial use of ground water in the United States. Abstract, Journ. Washington Acad. Sci., vol. 39, No. 3, pp. 105-106, Mar. 15, 1949. (To be published in Proc. Geol. Soc. Amer.)

MODERN SOIL SCIENCE ¹

By CHARLES E. KELLOGG
U. S. Department of Agriculture

[With 2 plates]

Most people probably think of soil as the loose surface material plowed in the field or spaded in the garden. At some time we have taken up a handful and let it run through our fingers, or squeezed it into a soft ball. We have seen sand grains, roots, and worms in it. Sometimes soil is hard, almost like rock; sometimes it is coarse and loose, like cinders and ashes; where most productive, soil is soft and mellow.

We cannot see or feel the chemical composition of the soil, but obviously it must contain a wide variety of elements and compounds. Some plants grow on every kind of soil, and we know that even the simplest plants require several nutrient materials besides the carbon, hydrogen, and oxygen they get from the air and water.

Starting with this simple concept, the making of chemical analyses of soils to increase our knowledge is a natural step, and indeed even the early chemists did this. By analyzing the soils and the plants growing on them it seemed logical to work out a balance sheet of plant nutrients. If the nutrients in a soil and the amounts required by plants are known, it seems reasonable to predict how many crops could be grown before the soil would be exhausted, what crops would be best, and what fertilizers would be necessary.

There were many difficulties with this simple concept of a balance sheet. Despite support from the great Justus von Liebig with his towering reputation, this theory failed rather badly on the practical side, and even worse on the scientific side. The fertilizer industry that grew up under the shadow of Liebig did develop useful fertilizers, and these increased yields, but the fertilizers were often inefficient and always uncertain.

It really is too bad that the balance-sheet theory was so inadequate, since it was refreshingly simple. But the soil is anything but simple. First of all, actual soil in the woods or garden is partly alive. It is quite unlike the dead samples of soil stored in the glass jars of chemical laboratories. A soil consists of thousands of compounds, organic and

¹ Based upon material presented in Sigma Xi National Lectureships. Reprinted by permission from *American Scientist*, vol. 36, No. 4, autumn issue, 1948, and *Science in Progress*, Series VI, Yale Univ. Press.

inorganic. Some of these compounds are highly active even when present in tiny amounts, whereas others, like quartz, are relatively inactive even though their bulk is large. The total chemical analysis conceals these important variations. One must turn to the X-ray, the petrographic microscope, the electron microscope, the spectrograph, and similar devices to discover the relevant materials. The soil is much more than the surface film stirred in tillage; it is the group of layers that make up the whole volume of the landscape, extending down as deeply as the living organisms themselves. In fact, soil is the essential link between the lifeless mineral body of the earth and the biological kingdom, including man himself.

THE SOIL PROFILE

If, instead of looking only at the soil in our garden, we look at many gardens, all sorts of differences among these soils are evident. Then if the soils across a continent are examined a close relationship among vegetation, climate, and soil becomes apparent. Subhumid grasslands and black soils go together; cool, moist climates and evergreen forests with light-colored soils; tropical rain forests with red soils, and so on.

Soils consist of several distinct sheets, one on top of the other. In an excavation or a cut these sheets appear as layers, or soil horizons. Of course, some layers in the soil are inherited from layers in the original rocks. But regardless of the original rocks, we shall find true soil horizons, resulting from the peculiar environmental conditions of the place. Taken together, from the surface down into the weathered rock beneath, a collection of horizons is called a soil profile. The soil profiles in different kinds of landscapes are strikingly different from one another, yet they are alike in the same kind of landscape wherever that landscape is found.

This recognition, about 1870, of a unique soil profile for each kind of landscape was the greatest single advance ever made in fundamental soil science, analogous to the development of anatomy in medicine. One does not need to depend upon inference from the geological nature of the rock, or from climate, or from other environmental factors, considered singly or collectively; the soil scientist can go directly to the soil itself. I hasten to add that rather than making the other sciences useless in soil study, this step in fact made them more valuable. Through soil morphology, soil scientists found a basis on which to classify the results of observations, of experiments, and of practical experience.

THE MATERIAL OF SOIL SCIENCE

The material of soil science covers the land area of the world. Thousands of kinds of soils exist. Due to the complex nature of its

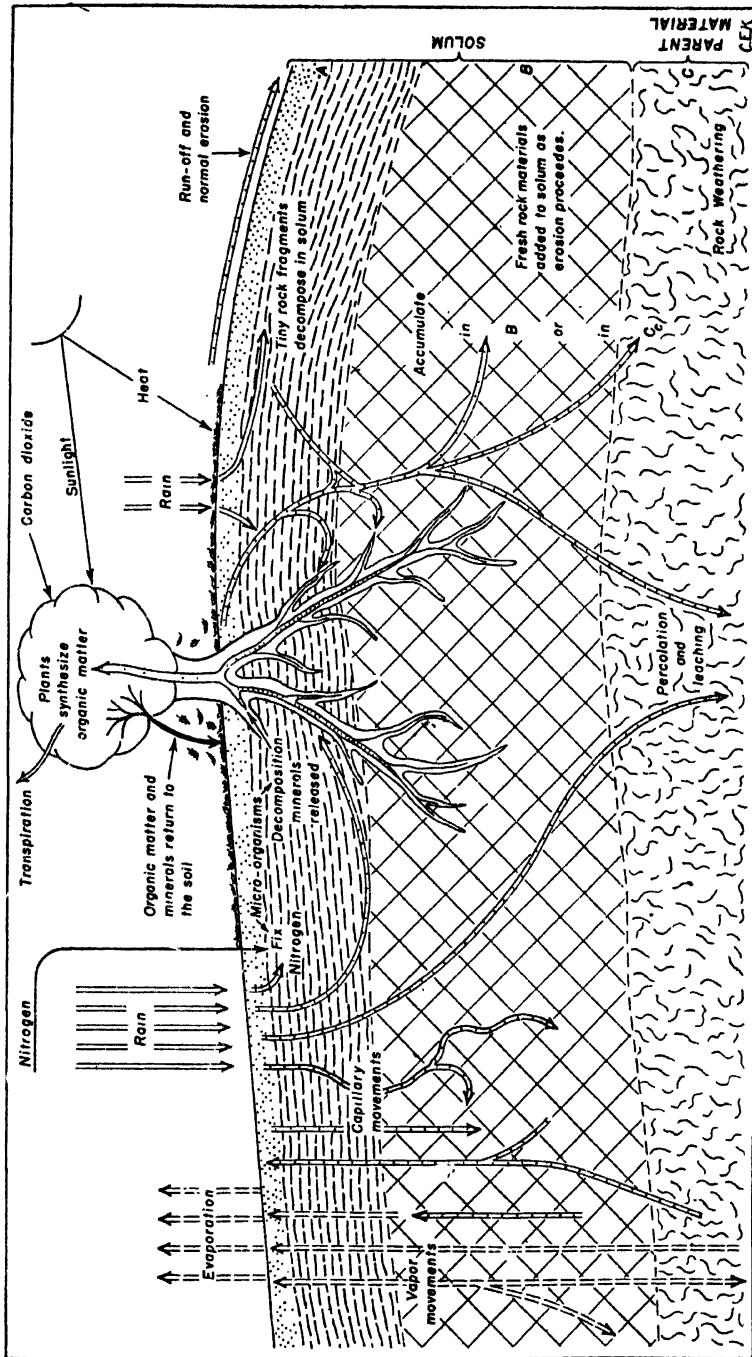


FIGURE 1.—This oversimplified sketch indicates many of the main processes going on in an ordinary soil. Plant roots remove water and nutrients from the whole soil, combine these with the carbon from the air to manufacture plant foods that are built into fruits, leaves, stems, and so on. These ultimately return to the soil to be decomposed, and the nutrients return again to plants. The macro- and micro-organisms of the soil are vital to this nutrient cycle and also in maintaining the structure of the soil.

materials, soil science is not easily classified as a science in the traditional patterns. Often it is included with the physical sciences, like chemistry and physics. Yet it is also grouped as correctly with the biological sciences, along with plant physiology and bacteriology. Then again, soil science is appropriately grouped with geology and geography as an earth science. Actually soil science uses the principles and methods of all three of these groups, and a soil scientist who uses the principles of only one or two of the groups, to the exclusion of the others, can only have small principles that have little prediction value and soon bog down in contradiction. In addition to those already mentioned, there are important principles and methods peculiar to soil science itself that do not belong to any other science. In application, the principles of soil science must be intimately related to those of the social sciences.

It needs to be emphasized that the experimental method and the method of scientific correlation are essential in both fundamental soil science and in the application of its principles to practical problems in farming, gardening, and forestry.

Soils must be studied in relation to one another and to the whole environment, both natural and cultural, to understand their formation and the influence of the individual factors of climate, vegetation, parent rock, relief, and time. How any one of these factors operates depends upon the others. The significance of any one soil characteristic depends upon the others. Any soil is a combination of characteristics, produced by a combination of factors, each of which influences the functioning of the others.

Experiments are needed, both natural and artificial, to learn how individual soils behave and how they respond to treatment. These must be specifically related to individual kinds of soil, however, if the results are to be used in developing principles or as the bases for practical predictions. Thus the experimental methods and the methods of scientific correlation are intimately interwoven in productive research in soil science.

SOIL AND LANDSCAPE

Let us look briefly at the implications of this concept of soils. They are natural bodies, each with its own unique morphology; they are dynamic bodies, developing with the natural landscape itself; they accurately reflect, at any moment, the combined or synthetic influence of the living matter and climate, acting upon the parent rock through processes conditioned by relief, over a period of time; they are distributed over the earth according to orderly discoverable and definable geographic principles.

The geological process of mountain building, rock formation, and landscape evolution from which the parent materials of soils originate,

are still going on along with soil formation. The natural erosion of the uplands gradually removes a little of the surface bit by bit while the soil film settles down, and fresh minerals are added to the soil from beneath. With the warping of the landscape these processes are accelerated or retarded.

At several of the Soil Conservation Experiment Stations of the United States Department of Agriculture, rates of erosion were determined under permanent vegetation (15).² Under the natural forest

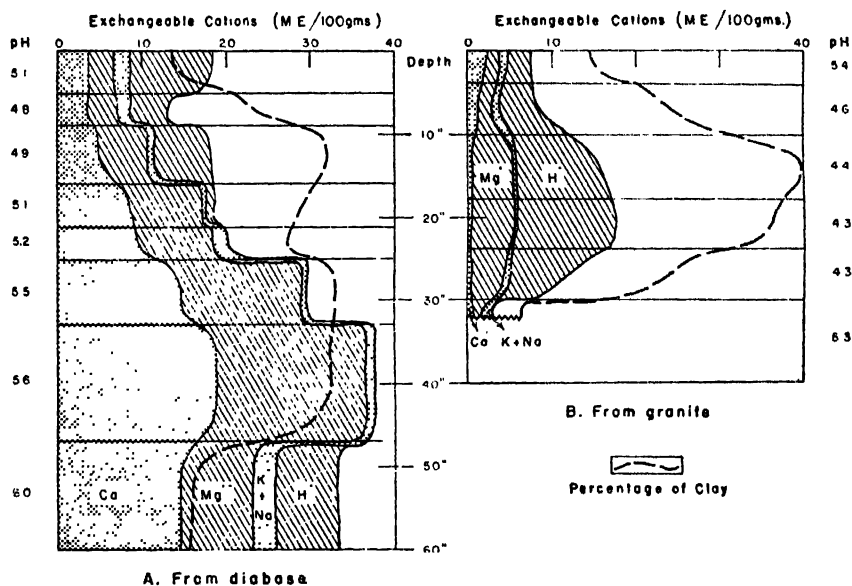


FIGURE 2.—A comparison of the clay content and exchangeable bases from two soils developed in similar environments, except for the difference in parent rock. The fundamentally important differences in clay content and in exchangeable bases are obvious between the soils and among horizons within each soil (9).

cover of the Cecil soil of the Piedmont, erosion proceeds at a rate of about 1 foot in 10,000 years. This value was determined on a 10-percent slope. Yet on a 14-percent slope of the Muskingum silt loam of Ohio, considerably over 200,000 years would be required to remove 1 foot by erosion under the forest cover.

Under a well-established grass cover, normal erosion proceeds slowly on the dark-colored soils developed under tall prairie grasses. On the Marshall silt loam near the Nebraska-Iowa line, with 9-percent slope, nearly 14,000 years would be required to remove 1 foot under bluegrass. On a black soil of east Texas, Austin clay with a slope of 4 percent, the figure is nearly 900,000 years.

²Numbers in parentheses refer to literature cited at the end of this article.

These values probably do not represent the real extremes, but rather relate to normal erosion. Some soils erode much more rapidly under clean cultivation with bad effects upon soil productivity. Through proper cropping systems and soil management practices, erosion of soil under use should be kept somewhere near the normal rate.

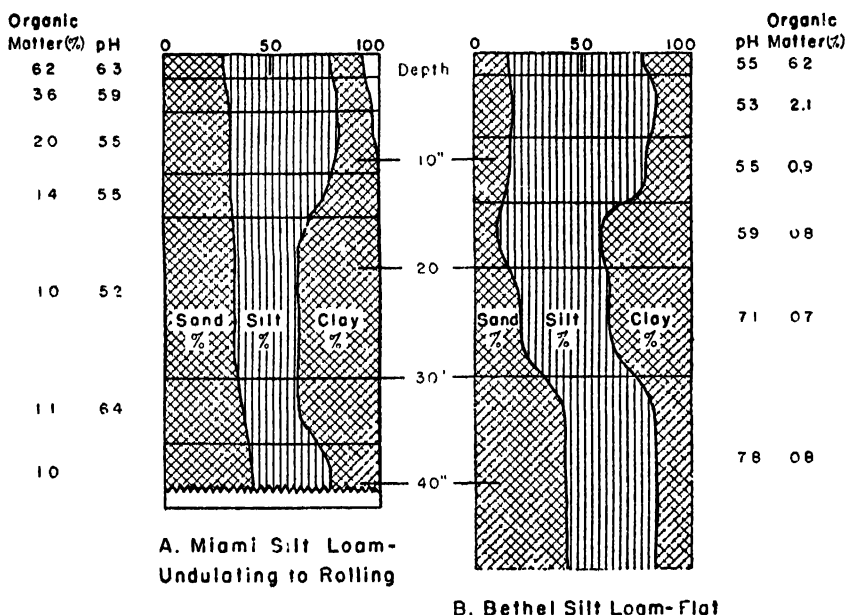


FIGURE 3.—A comparison of the mechanical composition of two soils developed from similar parent materials and in similar environments, except for relief. On soils of undulating to gently rolling relief there is continually a small amount of erosion in the natural landscape. As the surface is thus slowly eroded, each soil horizon works down into the one beneath. Over a period of several thousand years the whole soil profile, while remaining at the same length, may sink into the landscape a foot or more. Thus the soil is kept constantly renewed with new minerals. This is illustrated by the Miami silt loam at the left. The soil at the right is developed from similar material on flat upland where there is little or no erosion in the natural landscape. The leached material accumulates at the surface, and clay formation and the accumulation of clay are accentuated in the middle portion of the profile, with the development of a claypan. Whereas the Miami silt loam is a well-drained soil, pervious to roots and water, the Bethel is an imperfectly drained soil. During wet periods excess water is held up by the claypan which is also impenetrable to most roots. Kinds of crops and soil-management practices for optimum production are quite different indeed, even though the soils lie side by side on the same farm (2).

Percolating water gradually dissolves the minerals in the soil and the rock beneath. Clarke has said that this process alone reduces the surface of the United States on an average of about a foot in 30,000 years (6). From a study of streams, Dale and Stabler (7) estimated

several years ago that the average rate of denudation for the United States as a whole was about 1 foot in 8,760 years, with suspended matter accounting for about 65 percent and dissolved matter 35 percent. Solution progresses much more rapidly than this in areas of soft limestone and high rainfall, and, of course, the process is almost infinitely slow on the hard rocks of steep slopes.

Other landscapes receive part of the erosion products and part of the solution products from the upland. It is probable that a third of the population of the world get their major food supply from alluvial soils recently rejuvenated by additions of fresh rock minerals to their surface. The Nile is a famous example. In flood stage the water of the Nile contains over 1,000 parts per million of suspended matter relatively rich in phosphorus, potassium, nitrogen, and other plant nutrients. Part of this covers the soil in the flood plain and part of it moves out into the sea. Barrell (1) estimated that the Nile Delta alone contains the equivalent of nearly 12,000 cubic miles of rock, to say nothing of the soluble material contributed to the sea water. According to Barrell's figures the rock material in the delta of the Niger River is equivalent to a wedge-shaped mountain range some 18 miles wide at the base, 3 miles high at the top, and 1,000 miles long.

This gives some idea of the enormous movement of surface soil material as a natural process. In addition, in the Tropics especially, volcanoes often shower the landscape with fresh rock or ash. A layer of ash only an inch thick amounts to 200 to 300 tons per acre of fresh fine rock material. Usually such ash contains significant amounts of calcium, potassium, magnesium, phosphorus, and other elements essential to plant and animal growth. Even nitrogen is sometimes present in important amounts. An acre-inch of the ash from Parícutin, the new volcano in Mexico, contains the equivalent of over 20 tons of ground limestone. Sometimes productive soils are covered with a rather sterile ash, but more often old leached soils are rejuvenated. In the humid Tropics productive soils are generally those that are young, recently developed from volcanic lava, or soils that are kept rejuvenated by the relatively rapid addition of fresh minerals from beneath as the surface erodes away, or by additions of alluvium or volcanic ash to the surface.

The most nearly dead soils are those on flat landscapes of high rainfall that are not rejuvenated by erosion, by new minerals entering the soil from beneath following natural erosion, or by sediments from above. These dead areas must await a new cycle of uplift and erosion before they become productive naturally.

THE MINERAL-ORGANIC CYCLE

We are interested in soil chiefly because it supports green plants, and from green plants all other plants and animals, including man himself,

get their food supply, either directly or from other plants and animals that live on the green plants. Of equal importance to this basic fact is the one that plants, and all the other living matter associated with plants, are chiefly responsible for the kind of soil developed. It can be stated that there is no life without soil, and no soil without life. Life and soil seem to have evolved together in a mineral-organic cycle, or rather in many cycles, because there are many kinds of plant associations, many kinds of landscapes, and many kinds of soils.

After the earth cooled into a solid surface, and before vegetation covered the land, it probably looked something like an extreme desert region looks today, with jagged hills, sharp angles, and deep, irregular stream courses. With the coming of vegetation, soils began to form. Landscapes became more stable; jagged peaks softened into round hills with gentle slopes. Vegetation not only changes the rock material, but holds it in place, allowing it to slip away only gradually and harmlessly.

The plants select the essential elements from the mass of rock material into which they extend their roots. The great bulk of most soils consists of various combinations of silicon, aluminum, and oxygen along with significant, but often tiny, amounts of the other 92 elements. Plants take in phosphorus, calcium, potassium, manganese, copper, and other elements which they require, and build them into characteristic fruits and leaves, bark and wood. As the leaves and fruits and other parts fall, and as plants die, this organic matter becomes in turn the food of bacteria and other decay organisms. With their help, the chemical decomposition releases the nutrients to the soil for other plants.

Estimates have been made of the annual production of organic matter in the natural landscape (10); unfortunately few data exist for the roots. For tall-grass prairie the figures for annual production are from around 1 ton to over 2 tons per acre. In temperate forests, values of around 3 tons per acre have been reported, with about one-half wood and one-half needles or leaves. Figures for tropical vegetation are much harder to determine, but estimates run up to 90 tons per acre per year. Of course, one year is but a moment in the life of a soil. But in 1,000 years a truly enormous influence is exerted on the soil by this root-sorting and the biological and chemical reactions associated with the production and decomposition of such vast quantities of plant material—quantities ranging from perhaps a low of 100 tons per acre through a medium of 3,000 tons, to nearly 90,000 tons, depending upon the kind of landscape.

To have some notion of the magnitude of this organic-mineral cycle in terms of a few specific elements, we might look at data for the annual leaf fall in ordinary hardwood and evergreen forests in northern United States (4, 5).

<i>Element</i>	<i>Pounds per acre</i>	
	<i>Hardwood</i>	<i>Evergreen</i>
Calcium.....	65.6	26.5
Nitrogen.....	16.6	23.6
Potassium.....	13.5	6.5
Magnesium.....	9.2	4.5
Phosphorus.....	3.3	1.8

These figures are broad averages and conceal significant differences among the specific organic-mineral cycles of individual soil types. Then too, the cycle varies in speed. In tropical areas it is very rapid: A small amount of a plant nutrient goes a long way since it is used over and over again in its rapid cycle from the soil to a plant, to the soil, and back to another plant again.

Thus it is clear that there is a continual cycle of nutrients out of the soil into the plants and back into the soil again. We are concerned both with the amounts involved and also with the conditions that affect them. In fact, the amounts by themselves can be misleading. Take calcium, for example: In the arid to subhumid regions the rainfall is insufficient to remove the calcium and it accumulates in a special horizon called the "lime zone" in the lower part of the soil profile. Calcium would not need to be added to this type of soil even after thousands of harvested crops. Yet in humid forested regions the leaching of calcium completely out of the soil is so great, in relationship to that brought up by the plants, that it must be returned to the soil in agricultural practice, either through the addition of organic matter or mineral amendments.

In the famous Kentucky bluegrass region the underlying rock is very rich in phosphorus. The soil contains supplies for thousands of crops. Yet in most parts of the world this critical element must be added by the farmer to supplement the natural mineral-organic cycle.

The kind of vegetation in the natural landscape has much to do with these vitally important cycles of elements. On the whole, trees do not require large amounts of phosphorus, and they do not preserve it in the soil to the extent that the grasses do. Thus when the vegetation is removed and replaced by the plant crops the soil is often found to be deficient in one or more of the plant nutrients. What man is doing is establishing a new landscape, an unnatural one, if you please. He must discover the appropriate mineral-organic cycle through trial and research, and then introduce practices to compensate for the change. This gets at the heart of the fundamental problem to which soil science addresses itself in its practical application to agriculture.

Soil fertilization, for example, is not simply a matter of replacing the nutrients removed by harvested crops. Some soils may be able to supply all or certain nutrients indefinitely; others may need heavy fertilization, far beyond what the plants take out, for long initial periods. Nor are we concerned simply with the effects on just one

crop or of the crops that can be grown on the soil anyway. Rather we must think of the various combinations of crops and practices, and their immediate and longtime influence upon the soil and upon one another, to the end that a combination will be developed which will maximize the ratio of production to labor and materials on a permanent basis.

LITTLE PLACES AND BIG PLACES

It is obvious that some sort of soil classification is essential, since the world has a great many thousands of kinds of landscapes, kinds of soil profiles, and kinds of mineral-organic cycles. Of course, one cannot deal with all these soils at one time, nor do they present equal contrasts. Actually, there are few sharp lines between soil types; rather the soil of the world is a continuum that may be divided into reasonably homogeneous units according to the state of our knowledge and the demands for accuracy and scientific prediction. The soil is a natural product, and no two soil profiles are identical any more than two oak trees or two college professors are. Soil types are man-made creations. In one soil type are included all the soils that appear to have the same kind of profile, even though they are not alike in every single respect.

This is not the place to go into the age-old problem of classification. All the natural sciences have the same problem. A classification is good to the extent that it serves the purpose of remembering characteristics, seeing relationships, and developing principles. A classification is bad to the extent that scientists become slaves to it, and twist their data and ideas to fit the classification. It improves as our knowledge grows. Some wonder when soil classification will "settle down"—when names and definitions will no longer be changed. This will happen when soil science has ceased to discover anything new—in other words, when it dies.

Let us now consider the significance of the lower groups, or local soil types, in contrast to the great soil groups, or continental soil types. The differences that are apparent between our garden and our neighbor's, or between one plot of crops or trees and the adjoining one, are differences related to the local conditions of rocks, relief, and age. The soil of one garden is derived from sandstone and another from granite; one garden is hilly and one is flat; one is on an old slope and one is on a young stream terrace. Associated with these differences are characteristics of great practical and scientific interest. Soils too sandy for gardens are often found mixed in an intricate pattern with soils that are too heavy in clay; soils too steep for cultivation with soils that are flat and wet. If these soils are studied carefully, one can determine how they differ from one another and what direct relationships exist between the soil characteristics and the factors of the environment. Nevertheless, serious errors may be made as to the

causes of soil characteristics, because of failure to see the common characteristics of unlike soils found in the same ecological region.

In a broader study one might reach altogether different conclusions. Suppose, for example, that one studies in detail the upland soils on smooth slopes from limestone and sandstone in West Virginia in contrast to those on smooth slopes from limestone and sandstone in western North Dakota and in southern Arizona. Here again, striking differences are apparent, but the most important of these relate to differences in climate and vegetation; geology would seem relatively unimportant.

Thus by grouping the local soil types into higher categories, the broad soil groups that dominate the landscapes of great regions are compiled. When one considers individual practices in the garden, on the farm, or in the forest, it is the local landscape and the local soil types that are important. When one considers the great movements of population, the potentialities of nations, and the historical trends of peoples, the significant factors are the great soil groups. Thus the gardener sees soil characteristics with a different emphasis than does the geographer, but soil science has much to contribute to both.

PRIMITIVE SOCIETIES ON THE SOIL

The soil supports plants, animals, and man himself. Primitive man must have been as much the helpless product of his environment as were the wild animals. He lived close to the soil and was a food gatherer. He took the plants and animals, including fish, that were available in his own landscape. Most of these were eaten with little change by cooking, storage, or refining. No doubt it was a risky business. Families might fail to get food because of drought, deep snows, wars, or other calamities, and starve. However, when things went well, although they might live on a few foods for a time, during the year there was usually a variety. Then too, primitive man ate vigorously. He ate whole foods—skins, hulls, seeds, and other parts that are now thrown away. It is only recently that modern man has attempted to create a balanced diet. Early man received or failed to receive his proteins, minerals, and vitamins, unconsciously. Of course, no scientist was available to study our savage ancestors at the time, but many studies have been made of relatively primitive peoples and of the physical degeneration caused by the substitution for native whole foods, like cereal grains, milk, cheese, fruits, and meat, of refined sugar, white flour, and similar products of more "advanced" societies (12). Thus native peoples may become degenerated, or even extinct, after contact with Western Europeans. There are reasons to suggest that people, like plants and animals, over a long period come to an adjustment with their food supply (11).

Marett held that people having food deficient in some essential element, say calcium, phosphorus, or iodine, gradually develop the ability to conserve this element. That is, in the evolutionary process the ability to get along satisfactorily with only a little of some element would have survival value. Such people would be most likely to have children able to thrive and grow strong. But in the process, size, skin color, and other features, even the psychological characteristics and social traits, are altered. Marett believed that differences in food composition, most of which were closely related to the local environment before the modern period, had a great deal to do with the origin of races, with the physical and social differences among the different peoples of the earth.

Marett argued, for example, that in regions with acid soils deficient in calcium, people of small size would be favored. The physiological strain of lactation upon females would be much greater in humid regions where soils are generally leached and acid and the foods deficient in calcium and phosphorus, than in arid regions where soils usually contain abundant lime (calcium). Thus on acid soils where food is deficient in calcium the bodily strain would lead to adjustments for economizing lime through decreased size, especially of bones. He suggested that the operation of these forces may have been important in the development of fine bones among modern people as contrasted to our more coarse-boned ancestors. Such changes are very gradual, and are not marked until after long-living in a particular landscape.

MAN AS A CULTIVATOR

As civilization developed, man became a cultivator. He began to direct the course of nature toward his own ends, and ceased to be simply a food gatherer dependent only upon the natural bounty of the landscape. He ceased to be primarily a thief, and became a grower, a homemaker, a planner, and a conservationist in the only sense the term has any social meaning. As he gained in experience he learned to satisfy himself more easily; in fact, some people in the society could cease to be food gatherers. Social structures rose with the evolution of trades and professions. As the efficiency of food production increased, more and more people could be released from food gathering to develop the arts and sciences, to make the other things man needed for his health and comfort, and, unfortunately, to make war.

From the dawn of history to the rise of modern science the accumulation of learning about agriculture was a terribly slow process. Experience, which was passed down from father to son over the generations, was the only guide. Only a few departures were made, because there was no substitute for such experience. Further, there was little

realization that experience on one soil, in one landscape, could not be relied upon where another soil was involved. Migrations were often disastrous for this reason. Then, too, world history records changes in the landscape under the very feet of the farmer, like the slow spread of the Sahara Desert as it gradually expands to its former position, following the moist period of glacial times (8).

Unfortunately, the early scientists of Greece and Rome reached little into the problems of agriculture. With a few conspicuous exceptions, the philosophers of that day accepted farming as the job of slaves, beneath the dignity of trained scholarship.

THE GREAT DISCOVERIES

The tempo of man's struggle with his environment completely changed with two great forces: the rise of modern science and the great discoveries. The most important fact of Western culture was the opening of new land in the world. The forces leading to the pessimism of Malthus were already destroyed before his famous essay on population had been printed. Science began to increase productive efficiency. Western Europeans found new homes in the landscapes of the Americas.

Europe had been bound by an aristocracy based upon land. Although many came to the new world to seek gold and adventure, most people came to find land and to build homes on the only security they knew. Gradually the east coasts of the new world filled up. In the beginning people were confined to land near the sea and to navigable waters, as they had been in the centuries before. But modern science came to the aid of discovery. The European colonists pushed into the interior, especially in North America. Railroads had made possible the exploitation of interiors of continents, of the great areas of black soils. Except for a few isolated spots, these soils were scarcely used by civilized folks at the time of the Treaty of Westphalia when modern nationalism had its birth. During the nineteenth century the black soils (Chernozem and Prairie soils) and the brown soils (Chestnut and Brown soils) in North America were occupied. The frustrated, the persecuted, the seekers of new opportunity had a place to go, and it was a good place with good soil. For over 200 years a man and woman could carve themselves out a farm home on the colonial frontier, in the Ohio Valley, on the great prairies of Illinois and Iowa, and finally on the Great Plains to the west. Grassland needed only cultivation, once transportation was established.

In addition to the fine soils, there were other free resources, the forests and minerals. There was land in North America, Central America, South America, New Zealand, and Australia. Following the great discoveries Europeans found opportunities throughout the

world. This progress is credited by many people to western civilization, but it would have been a poor civilization indeed that could not have succeeded with these riches. With such abundant resources for its citizens, it is hard to imagine how any American government could possibly have failed.

At the present time, however, people must make a go of things where they are, or else move into areas where a great deal of careful planning is necessary for successful agriculture or industry. There is no more

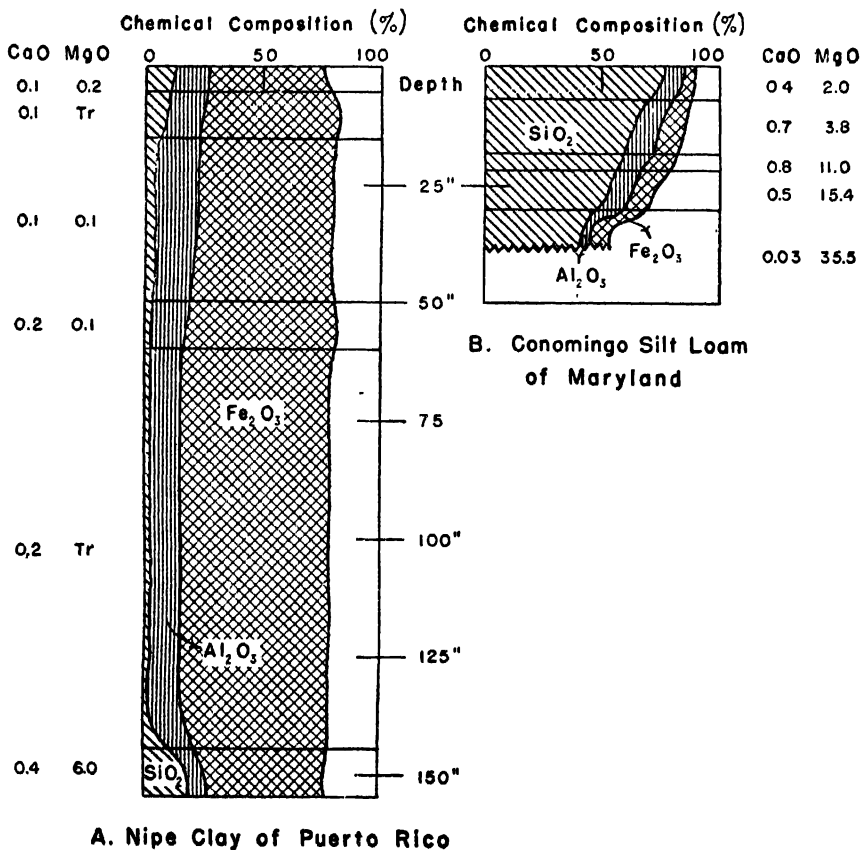


FIGURE 5.—A comparison of some of the chemical properties of two soils developed from similar serpentine rocks, one in tropical Puerto Rico, and one in temperate Maryland. Under temperate conditions the silica has been preserved, whereas it has nearly all been removed under tropical conditions. Further, under tropical conditions there has been an enormous increase in the amount of iron, and the tropical soil has been affected by weathering and soil-forming processes to a much greater depth. Of course, along with these obvious chemical changes are a great many other changes reflected in the mineralogical composition and physical properties of the two soils. Both of them are relatively unproductive naturally and require quite different methods for their improvement (14, 15).

fertile soil in the world waiting only for the plow. But there is a great deal of unused land in the world that can be made productive through the application of modern science, land that is made up of thousands of unique types of soil.

MODERN SCIENCE

The great discoveries themselves owe much to modern science. An insignificant part of the bread grains of the world were grown on the black Chernozem soils of the subhumid grasslands when the Treaty of Westphalia was signed. Now these same black soils are contributing more than one-half the supply of bread grains to the world. Within some 250 years man has occupied these soils. At first he applied the old methods and the old traditions, with poor results. Then from modern science he received railroads, proper machinery, and power. Whereas 100 years ago most cities of importance in the world were located on Gray-Brown Podzolic soils, like those of the Ohio Valley and northwestern Europe, now there are great cities on the black soils and on the brown soils like them. In fact, the great modern army that stopped the Germans at Stalingrad was raised on these soils.

Our early application of science to make a better adjustment between man and his environment was uneven. The various sciences have developed unevenly, and they are applied unevenly in different parts of the world. Early attempts to build the Panama Canal showed the failure of engineering without medicine, and there are similar failures of engineering and medicine without improved husbandry. Soil depletion due to erosion in parts of Africa has followed attempts to buy the wares of the peddler before husbandry had improved the efficiency of agriculture. In fact, soil depletion through accelerated erosion, exhaustion of plant nutrients, accumulation of excess salts, and loss of mellow structure follow the decline of the people. The great opportunities for future development depend not on science alone but on a symmetrical science.

Of course, some object to machines and the planning inevitable to the use of science. They talk about going back to nature. But obviously this would not be possible unless we were willing to do away with a large part of our population and with all our modern gadgets. Scientists, and agricultural scientists in particular, were blamed by some for the last great depression. It was said that if scientists had not developed all these new methods surpluses and low prices would not have existed. Of course, this appears ridiculous to a scientist, since millions of people are in need of essential food and clothing for health. To the scientist surpluses are market phenomena within man's control and due to imperfections that are subject to control. The good life requires abundance, and abundance depends upon the efficient use of all our knowledge.

Returning to the relationship between man and the soil, or landscape, where he finds himself: the optimum or ideal adjustment can be approached by changing the environment, changing the soil, or by man adapting himself to the environment. Actually, of course, man does some of both, and science helps both processes. From our understanding of the soil and the environment we learn how to change it, and how to adapt ourselves to it.

The soil is not easily changed, however, for in spite of all we learn to do through husbandry there still remains a closer relationship between the quality of foods and the natural soil type than there is between their quality and modern agricultural practices. Of course, irrigation of the desert or drainage of swamp land by means of large-scale engineering devices brings an immediate change. But most changes come slowly and often indirectly. A little change in the soil can set into motion a whole series of fundamental changes.

For example, most of the soils developed in humid forested landscapes are acid. Although they are productive for a time, these soils produce only a few of the plants man needs. By adding some lime, often some phosphate, and sometimes some other materials in relatively small amounts, the farmer can widen his choice of crops. He can grow the deep-rooted legumes where he could not before. These crops, in turn, have a pronounced influence on the soil and upon the crops that follow them. Similarly, the farmer in the humid region can develop a soil approaching the notoriously productive Chernozem of the subhumid grasslands by making up through fertilization for the extra leaching in the humid climate. Although fertilizer has not been found to have a dependable influence on the quality of food crops, through fertilization the farmer can so expand his range of crops that he can select those most nutritious for animal feed and human food.

Every natural soil has certain limits to its potentialities. Through modern science these limits may be expanded in terms of kinds of crops and yields. *No very close relationship exists between the natural fertility of soils and their actual productivity in society.* The important factor is their response to management. Some of the most productive soils in the United States are in the southeastern region, soils that are notoriously infertile when first cultivated as compared to the black soils of the Middle West.

NEED FOR SYMMETRY

Man's adjustment to the natural soil is not merely a matter of doing a few things. It is the process of substituting a new environment, with all its varied effects on living matter and the dynamic processes within the soil, for the old one. With the smooth-lying soils of the Iowa prairies the farmer gets nearly maximum yields from his first cultiva-

tion; in fact, there is no practical way now known to maintain the nutrient supply and productivity of these soils as high as they were under continuous grass and still use them for crops under anything like present economic conditions. However, these soils can be maintained in cultivation at a slightly lower level of productivity under practices that maintain the nutrient supply and organic matter and control the water supply to avoid excess run-off and erosion. This is to be expected, since these soils were developed under grasslike plants, similar to the crops the farmer wants to grow.

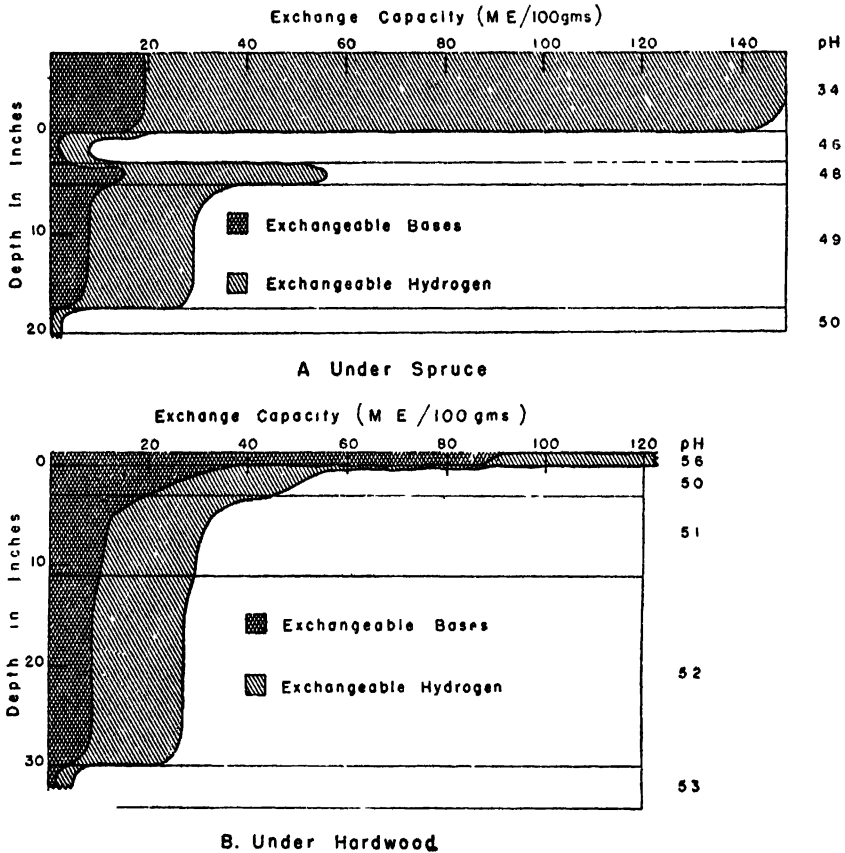


FIGURE 6.—These graphs illustrate a comparison of total exchangeable bases and exchangeable nitrogen in two soils developed under similar environmental conditions, except for the vegetation. Because the spruce needles and twigs decompose slowly there is a considerable accumulation before decomposition is equal to the annual drop from the forest. Since the hardwoods drop nearly twice as much calcium and other bases each year, soils developed under hardwoods have a relatively higher amount of exchangeable bases. The upper chart indicates clearly the horizon of extreme leaching lying almost directly under the organic mat of a Podzol (3).

The situation is different when the forest is removed from a leached soil in the humid region. The organic matter and nutrients must be built up far above the levels present in the natural soils, and the balance is delicate, both the natural balance and the one created by man. Too much lime added, and other nutrients become unavailable. Too much nitrogen added, and plants are weak, poor in quality, and easy prey to diseases. Water control without proper fertility may be impractical and wasteful. Rarely can the maximum economic production from soils in humid forested regions be realized by application of just one or two scientific practices.

CONCLUSIONS

In the past, the environment determined man's development and set definite limits on his activities. His music and architecture, his economic and political institutions, in fact, his whole social being was strongly influenced by the potentialities of the soil. As modern soil science develops further, the environment will determine less what man is and more what he does. Scientists will learn more precisely how to carry specific management practices from one soil to another, in order to achieve good productivity.

As science progresses there will be increasing emphasis upon symmetry in science, upon fitting the parts together. Although such an emphasis runs counter to the modern trend of specialization, organizational devices both in research and education will be created so that teams of scientists of different specialties work together. Only in this way can even a small part of our agricultural potentialities be realized or more than a small part of our soil science be put to work.

Even now, there would be enough food if soil science were used to the fullest extent. There are no apparent limits to our potentiality; it is far away, far beyond our present production. Even in this great country there is needless inefficiency in agriculture, needless from the standpoint of proved scientific principles and practices. Some farmers do not know what to do; others have no way of knowing, or of following the practices if they did know. Thus even on the soil already occupied, the opportunities for more food are enormous. In addition, there are still areas in the interior of continents that are only partly used for lack of industry or transportation. This is especially true concerning Asia.

Even more important than these wasted opportunities are the great areas of tropical soils. Some say that the resources of the Tropics are almost without limit; others say they are nil. The truth is that without modern science their productivity is small; thus it might be said that the Tropics are overpopulated now. However, with the application of a symmetrical soil science, the potentialities of the Tropics are

enormous. Most of the soils are naturally infertile in terms of our present practices in temperate regions, but it is possible to modify the mineral-organic cycle of these soils and get good production of cultivated plants on a secure basis. All the agricultural sciences will be involved, along with soil science, medicine, engineering, economics, and political science.

This outline of soil science in modern society leaves a million details untold. If peace and abundance in the world are achieved, thousands of soil scientists will have contributed their whole lives toward it, along with other people. The data of soil science show that abundance is possible. Whether it should be achieved, and whether it will be achieved, are not scientific questions. But if the people of the world decide that they want peace and enough food, and if they address themselves to the economic and social problems standing in the way, soil science says it is possible.

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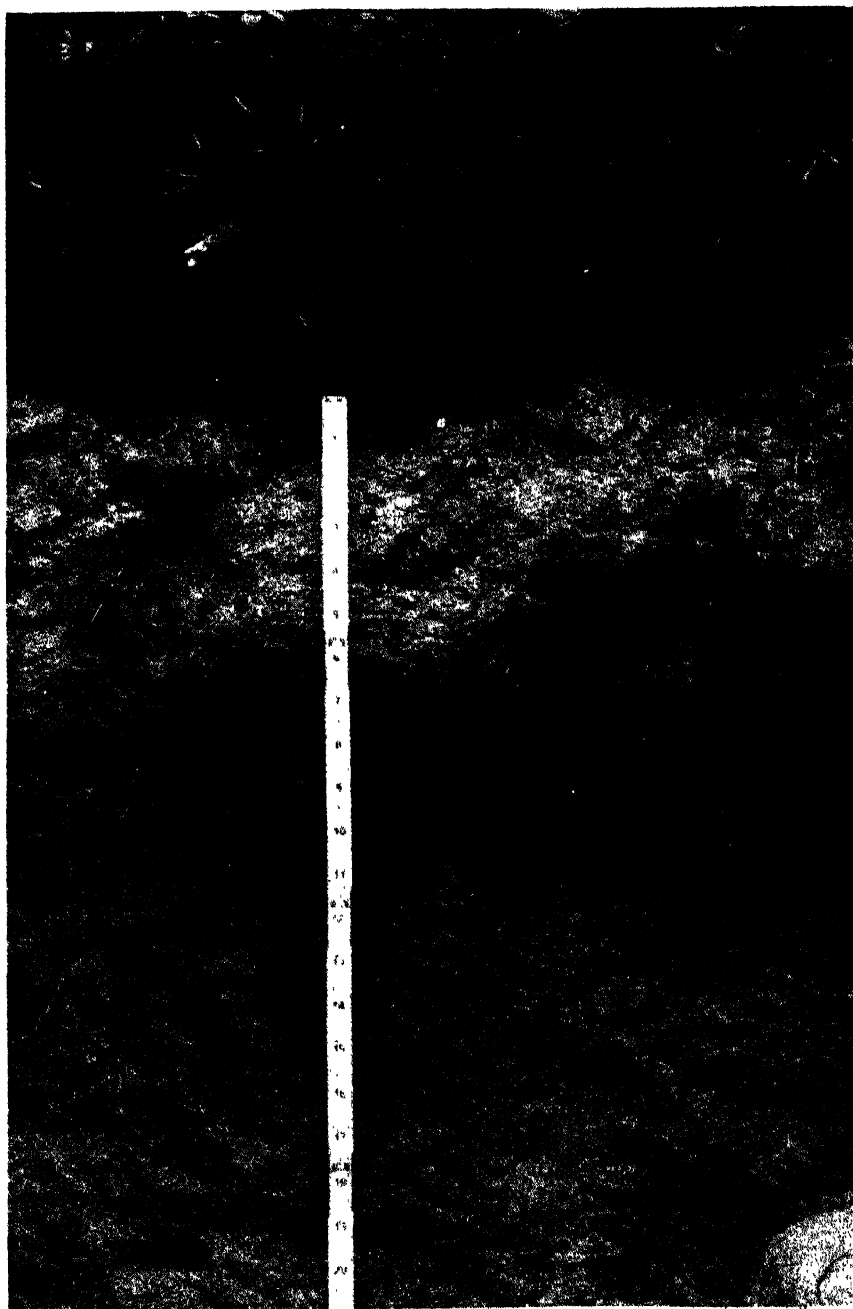
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PROFILE OF A PODZOL SOIL IN MAINE UNDER THE EVERGREEN FOREST

A heavy mat of partly decomposed organic matter from the forest lies over a nearly white, strongly leached horizon. Directly beneath this is a dark brown horizon containing colloidal material originating from the horizons above. In this region soil-forming processes do not extend deeply. The parent material—glacial drift—lies at about 20 inches.



4, profile of a dark-colored soil developed under tall grasses in Iowa (Webster clay loam—a Wiesenboden). During its development drainage was poor, which has intensified the effects of the grasses in producing abundant supplies of humus and kept leaching at a low point. When drained this is one of the most productive soils in the world for the crop plants of temperate regions. (Photograph by Dr. R. W. Simonson.)
 B, profile of a light-colored, leached soil developed under forest in the humid Atlantic Coast Plain (Ruston sandy loam—a Red Podzolic soil). In this environment little humus accumulates in the soil and leaching is active. The thick black layer so prominent in the Webster soil is essentially absent. Colloidal material has left the surface horizon, and part of it has been moved to the layer beneath. The peculiar mottling of the soil in the lower part is characteristic of those developing in warm humid climates. Although not naturally productive for crop plants, this soil can be made so through proper fertilization to supplement the plant nutrients already in the soil, crop rotations that emphasize the deeply rooted legumes, and by water-control systems that prevent accelerated run-off and erosion when cropped. (Photograph by Dr. R. W. Simonson.)

TIME IN EVOLUTION¹

By F. E. ZEUNER, PH. D., D. SC.

*Professor of Environmental Archaeology
University of London*

The study of evolution has proceeded along two different lines. While biologists were able to investigate the intimate structure of the cells composing living organisms and thus to unravel aspects of the mechanism of evolution, paleontologists supplied us with evidence for the succession of the forms of life. Broadly speaking, biological evidence has suggested that changes in the characters of species are sudden and paleontological evidence that they take place gradually. Apart from the problems connected with the causes of evolution (which are outside the scope of this discourse), there is involved in this difference the problem of time.

It was, therefore, only natural that workers on evolution were interested in the question of how much time was required to bring about certain changes in the characters of animals and plants. This chronological aspect of evolution was stressed by the early evolutionists, like Lamarck, Darwin, Wallace, Weismann, and Eimer. But paleontology and stratigraphy could do no more than provide a relative chronology of evolution. For the actual time involved there were only guesses available which were so divergent that no conclusions could be based on them. No wonder, therefore, that the time aspect of evolution was neglected by the later generations of workers. The guesses did agree, however, in one respect: that, measured by human standards, the time available for evolution was very long.

Since the end of the last century, however, geology has developed several methods of estimating geological time in years. Sequences of annual deposits, climatic and astronomical cycles, time rates of sedimentation and the decomposition of radioactive substances have been used in a great variety of ways, and the branch of geology which is called geochronology, has produced a number of time scales covering the entire history of the crust of the earth. As is to be expected, many

¹ Presented at the Weekly Evening Meeting of the Royal Institution of Great Britain, Friday, December 3, 1948. Reprinted by permission of the Royal Institution, with slight alterations and additional figures.

parts of the time scales are uncertain and the margin of error is often considerable. But an order of magnitude is gradually emerging and various portions of the time scales have been checked by independent methods and adjusted to each other. They have thus become useful instruments for the reconsideration of the time aspects of evolution.

It is my intention to introduce you to this fascinating subject. Within the limited time available only a few interesting examples can be given. The treatment of facts and problems will inevitably be sketchy, which means that some of my remarks will overstate the case, while others, which might appear to be overstatements, are not overstatements. In order to show the applicability, or otherwise, of some of the apparent rules to different branches of the tree of life, examples have been selected from as great a variety of groups as possible.

Let us first discuss the rate of changes in direct lines of descent, disregarding the phenomenon of splitting or branching of the phylogenetic tree. What I mean is illustrated by the pedigree of man, in which the numerous branches leading to other groups have been omitted. In order to attack the problem of the time rate of evolution, such a generalized and tentative pedigree is of course useless. It is necessary to consider a group for which a close succession of abundant fossil material is available. Such a group is that of the horses, which has been well studied in the United States. In figure 1 the chronological order and the range in time are shown for successive genera directly ancestral to *Equus*, the modern horse. From this arrangement, Simpson has deduced the average duration of a horse genus as about $5\frac{1}{2}$ million years. In column III, the horse's ancestors are spaced in accordance with the amount of structural modification between successive stages, and the amount is measured in arbitrary units. It is evident from the comparison of columns I, II, and III, that the morphological step, for instance, from *Epihippus* to *Mesohippus* was great, though it did not take more time than the preceding one from *Orohippus* to *Epihippus*. Evolution appears to have been accelerated in this case, as also from *Parahippus* to *Merychippus*. The remainder of the diagram shows the kinds of morphological characters used in assessing the units of column III, and also the trend of evolution in the horses.

This evidence supplies us with some interesting information, namely (a) that the rate of morphological change is not a simple function of time, and (b) that the average period of existence of a horse genus is of the order of a few million years. The horses have further provided an observation made by Stirton, which is worth mentioning. In studying the progressive increase in height (hypsodonty) of the cheek teeth, he noticed that at any one point of the lineage there is not enough individual difference in the height of the cheek teeth,

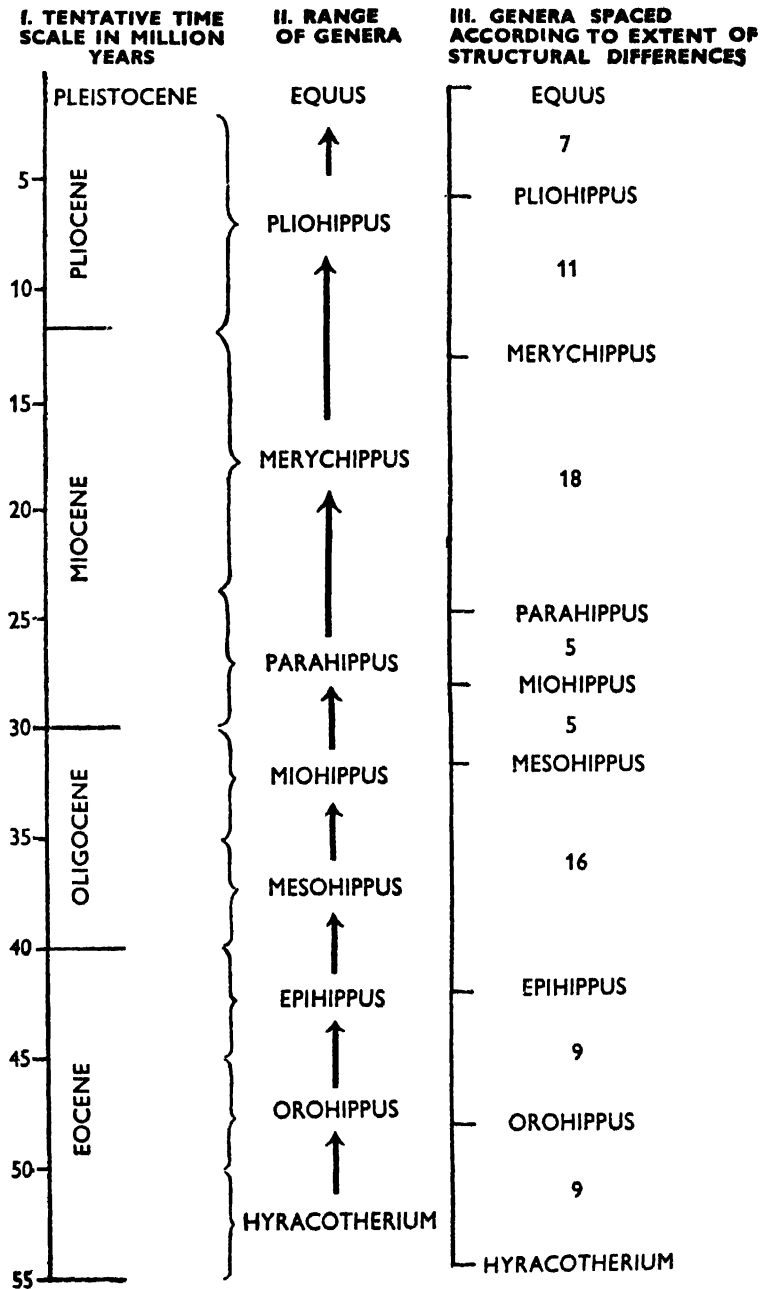


FIGURE 1.—The evolution of the horse in North America correlated with the absolute time scale. (Based on the work of E. D. Cope, W. D. Matthew, W. B. Scott, G. G. Simpson, R. A. Stirton, and others.)

nor even in successive species of ages as much apart as 1 million years, to believe that the minute differences present had any value as a determining factor in survival.

Returning to the duration of a genus, it will be interesting to consult other groups, to see whether the figure of $5\frac{1}{2}$ million years found in the horses is more generally applicable. Similar values are found in other groups of Mammalia, such as the land carnivores. For these Simpson constructed a "survivorship curve" showing that the mean duration of a genus of carnivores is $6\frac{1}{2}$ million years. But for the bivalve Mollusca, he obtained a mean as high as 78 million years.

Just to add a few more figures: Swinnerton found 20 million years as the average lifetime of a genus of Triassic ammonites. *Lingula*, on the other hand, a brachiopod, has been known for its persistence since the Cambrian. This genus has lasted over 400 million years. From this evidence the terrestrial Mammalia appear to have genera of a short duration, but even this is a matter of a few million years.

One might be inclined to interpret these different rates of generic evolution in terms of *species steps*, assuming that each lineage would pass through several evolutionary changes, each constituting a new species, before the accumulated differences justify one in calling the descendants a new *genus*. It is certain that this process underlies the evolution of the horse, but it is conceivable that in other groups genera may have originated without the interposition of a series of species steps. The time rate of species formation, therefore, must now be considered.

Selecting again terrestrial forms of life, mainly mammals, as our first examples, because more detailed evidence is available, we find that since the end of the last glaciation, some 10,000 to 20,000 years ago, only minor subspecies have appeared. The differences are confined to body size, color, slight differences in body proportions, in the development of appendages, etc. The British race of the red deer, for instance, has evolved since Britain became separated from the Continent some 7,500 years ago. This is shown by fossil evidence, since the early postglacial specimens found in the Thames belong to the Continental race. Moreover the characters of *Cervus elaphus scoticus*, as the British race is called, are probably not fixed genetically, since, when the breed was transferred to a favorable environment, in New Zealand, it reverted in many respects to the Continental type. Other examples could be given of the insignificant character of Postglacial differentiation in species.

Greater differences are observed in some, but by no means the majority, of Upper Pleistocene species, of about 50,000 to 100,000 years ago. For the marmot of that time, for instance, Wehrli found that the shape of the temporal ridges has since become stabilized.

These ridges run into the upper posterior edge of the processus postorbitalis in a certain number of fossil specimens, while in recent *Marmota marmota* they have moved to the upper side of the processus. That this character has become practically fixed since the Upper Pleistocene, is shown by the following figures:

TABLE I

	<i>Marmota</i> type (Percent)	Inter- mediate (Percent)	Primitive type (Percent)
Upper Pleistocene-----	33	53	13
Recent-----	98	--	2

Forms of this degree of variation would, in the recent fauna, be regarded as subspecies.

Going back to the Middle Pleistocene, about 250,000 years ago, the differences become more conspicuous, but they are still treated as subspecific by most taxonomists. It is only in the Lower Pleistocene, about 500,000 years ago, that we encounter ancestral forms on which the taxonomists agree that they must be classified as distinct species. This applies, for instance, to the European elephants, *Elephas antiquus*, and the mammoth, which Soergel has shown to have evolved from an early Pleistocene common ancestor, *Elephas meridionalis*. If this view is correct, nearly half a million years were required to produce a new species by way of a gradual change. If it is not correct, the point of divergence lies farther back in the past and the rate of species change is longer. In the lineages of rhinoceroses, bears, and deer, similar evidence is available and there are cases in the Recent fauna which have been explained as the results of geographical isolation during the glaciations (the common crow and the hooded crow, for instance). But again there are species which have changed much less since the Lower Pleistocene, which are regarded as no more than subspecifically distinct from their Recent descendants and, therefore, must have a slower rate of species formation. In the Cromer Forest Bed (about 500,000 years ago), 14 percent of the species are regarded as "Recent," though it is quite likely that subspecific differences will be detected by future revisers.

Five hundred thousand years, then, appears to be a fast rate of species evolution in terrestrial mammals and no faster rate has, to my knowledge, yet been found in other groups of the animal kingdom. Let us now consider the question, how long have species remained stable or unchanged? To answer it we have to resort to marine groups. Lower Miocene Mollusca of Java, for instance, are regarded as conspecific with Recent forms. They have been stable for 30 million years. Surveying fossils in general, this has to be regarded as a high figure, but it need not be a maximum.

It is conceivable that plant species behave differently. Small has analyzed several groups of plants from the chronological point of view, notably the diatoms. He came to the conclusion that the mean duration of species is measured in millions of years. Furthermore, he distinguished in the diatoms long-lived species (up to 100 million years) and short-lived species (one million years or less). In other groups he encountered shorter rates than this. These time rates are of much the same order as in the animal kingdom. But there is one interesting difference: while in animals the evidence suggests gradual change of specific characters, Small regards the changes in the diatoms (and perhaps other plants) as sudden.

Summarizing, we may say that half a million years is a short lifetime for a species and, so far as our admittedly incomplete evidence goes, something like a minimum. The lifetime of genera appears to be rarely less than 5 million years. Short rates are observed in terrestrial groups like most Mammalia, while long rates are frequent in mainly marine groups like the bivalve shells and the diatoms. There appears to be a certain amount of correlation between the rates of species evolution and the degree of changeability of the environment, slow rates being frequent in environments like the sea in which living conditions are exceedingly stable.

Hitherto we have been discussing changes in single lines of descent. Let us now consider the phenomenon of phyletic splitting. Branching is a frequent event in phylogenesis. An ancestral species may evolve into two divergent descendant species by the disappearance of intermediates, or the ancestral species may remain unaltered and a new type emerge as a side branch. In fact, few groups would survive without splitting, since owing to the action of internal (genetic) and external (environmental) factors, many species become extinct.

If the rate of splitting equals the rate of extinction, the number of species in a systematic category, like a genus or a family, remains constant. But if the rate of splitting is greater than the rate of extinction, the number of species in the group under consideration will rise increasingly steeply along an exponential curve.

There are many different ways in which the rate of splitting can be plotted in relation to time. I have selected two simple methods of plotting which can be applied readily to any group from which sufficient fossil material has been adequately studied by a taxonomist. One is to plot the number of species existing in any period or sub-period, or smaller stratigraphical division, on the absolute time scale. The other consists of doing the same for the newly appearing species only. In the first, the surviving species modify the picture. The second is a truer presentation of the rate of splitting, but the material is often not complete enough for its application.

Now let us consider a few examples. Figure 2 shows the genus *Salenia*. These sea urchins start in the Lower Cretaceous. The number of species rises rapidly to a climax in the Upper Cretaceous ("increase phase"). Cases like this one, of a rapid, almost sudden, blossoming-out of a group were called "explosive evolution" by Schindewolf. We may borrow the term and call the phase of rapid increase the explosive phase. In *Salenia* it is followed by a catastrophic drop followed by a slow "decline phase" leading to almost complete extinction. Of the cause of this sudden drop we are completely ignorant; it is an unusual feature, as will be seen when other diagrams are considered.

As regards the increase phase, we learn that in *Salenia* it lasted for about 40 million years.

Figure 3 shows the Brachiopod genus *Lingula*. Again it reveals a rapid rise in the number of species at the beginning, from the Cambrian to the Ordovician, of the order of 40-50 million years. But between the increase and the decline phases, a more or less "stationary" phase is intercalated, during which the number of species did not vary greatly. The decline phase of *Lingula* set in with the Carboniferous. It is a long-drawn-out phase and continues into the present.

Another interesting case is that of the coelacanths, a group of the fringe-finned fishes or Crossopterygii (fig. 4). This group never had a truly explosive phase. Nevertheless, there is an increase phase from the end of the Devonian to the Triassic, lasting about 100 million years.

One more example may be given, the molluscan genus *Poiretia* (fig. 5). Here, the explosive phase in the evolution of the genus is 30-40 million years. Other examples confirm that the length of the explosive phase is of the order of a few 10-million years, the extremes so far found being 30 and 100 million years and the mean around 50 million years.

As an example from the plant kingdom, illustrating at the same time a group with stable, geometrical characters living in an environment which changes but little, diatoms may be shown. Small investigated the chronology of their evolution, and the diagram of *Hemiaulus* shown (fig. 6) is a translation into our method of plotting of one of his diagrams. It shows a steepening rise to a climax in the Cretaceous. The increase phase lasted about 80 million years, no longer than in groups living in less stable environments, but there was a pronounced initial lag phase.

Now it is interesting to consider some higher systematic categories. One might expect that the explosive phase in the evolution of higher systematic units, like families, orders, classes, is longer than in genera. But this is not so.

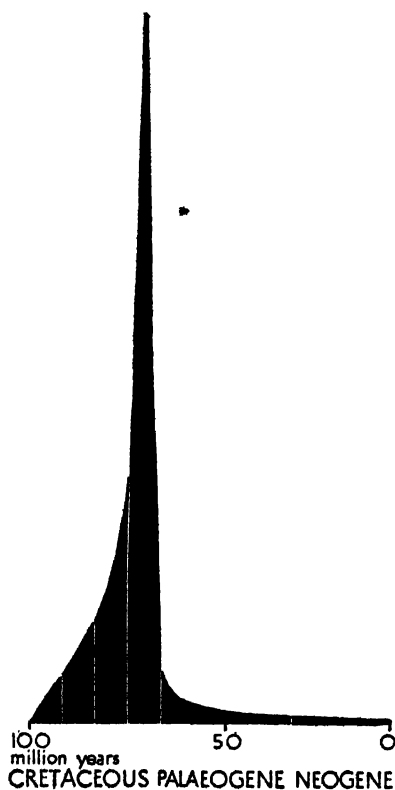


FIGURE 2.—Diagram of the numbers of species in the sea-urchin genus *Salenia* from the Cretaceous to the present day. (Surface area proportional to the number of species.)

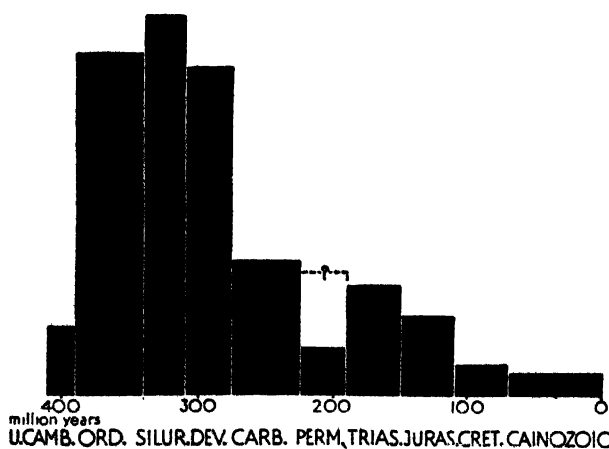


FIGURE 3.—Number of species in the brachiopod genus *Lingula*, from the Upper Cambrian to the present day. (Surface area proportional to the number of species.)

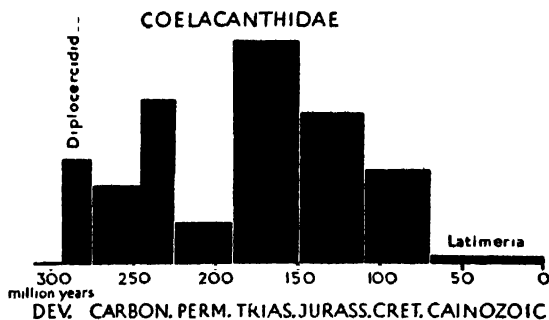


FIGURE 4.—Diagram showing frequency of species of coelacanth fishes in relation to time. In the Upper Devonian the family Diplocercididae flourished. In the Carboniferous it was replaced by the Coelacanthidae, which reached their climax in the Triassic. The small number of coelacanths recorded from the Permian may not represent their true frequency owing to the fact that relatively few marine deposits are known from the Permian. Possibly, therefore, the rise to the climax in the Triassic was not interrupted in the Permian, as is shown in the diagram, but was continuous from the Lower Carboniferous; if so, the rise would have taken about 100 million years and the rate of evolution would then be one of the slowest known. The coelacanths are regarded as a very conservative group which changed but little in the course of time.

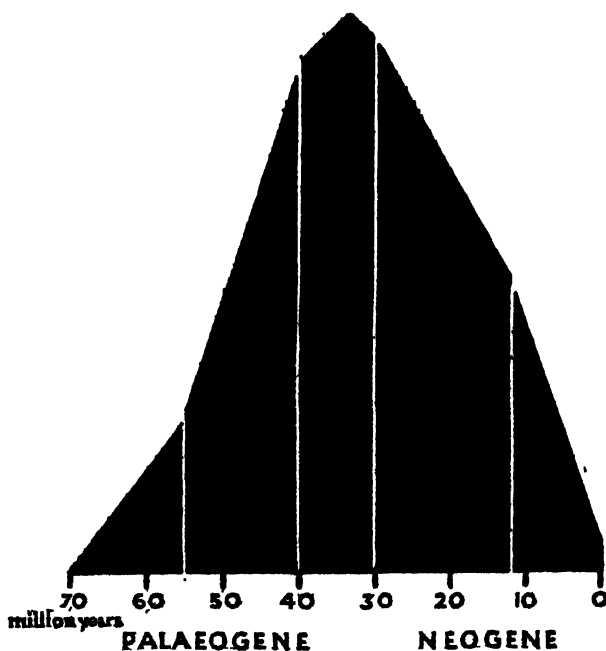


FIGURE 5.—Diagram showing the number of new species of the molluscan genus *Poiretia* appearing in the different subdivisions of the Tertiary. The maximum number of new species was produced in the late Palaeogene, within 30 to 40 million years of the appearance of the genus.

The first example of this kind is that of the rotaliid Foraminifera (fig. 7), showing the number of existing genera in the superfamily. Again there is a phase of steepening increase. It lasted from the early Cretaceous into the Oligocene, for about 70 million years. Another case is that of the genera in the brachiopod family, *Spiriferidae*, with an explosive phase of about 80 million years. A third example shows the orders in the class of the true fishes. This diagram

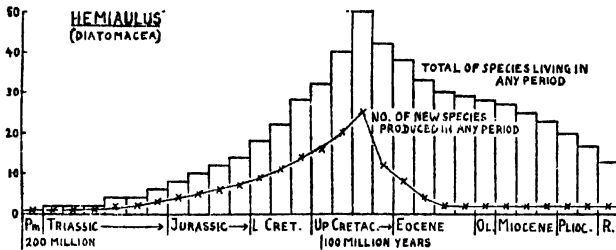


FIGURE 6.—The diatom genus *Hemiaulus*. The number of species living in any period (blocks) and the number of new species appearing in any period (curve) from the Permian to the present day. (Numerical material from Small, 1948. Ordinate scale linear.)

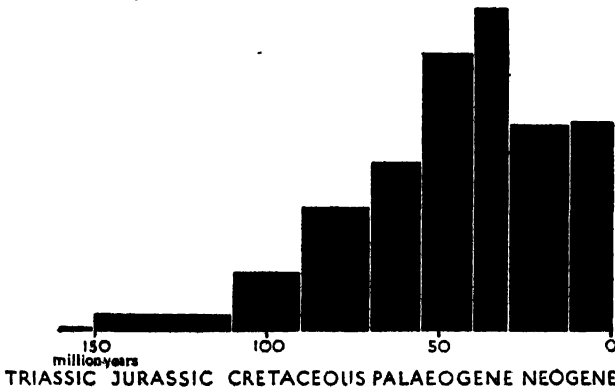


FIGURE 7.—Diagram showing the number of genera in the superfamily Rotalioidea (Foraminifera) present in various geological epochs. (Surface area of blocks proportional to the number of species.)

(fig. 8), which is based on Romer's work, is not strictly to scale, but there is no doubt that orders like the sturgeons and gar pikes had explosive phases of some 20–60 million years.

Finally, the number of orders within the class of the winged insects (Pterygota) must be mentioned. Since about a hundred orders have been distinguished, it is possible to plot them in much the same way as species in a genus. Once more, an explosive phase emerges, an exceptionally large number of orders appearing during the Upper Carboniferous and the Permian, over a period of about 60 million years.

TABLE 2.—*Insect orders*

	<i>Existing</i>	<i>New</i>
Devonian.....	0	0
Lower Carboniferous.....	2	2
Upper Carboniferous.....	18	16
Permian.....	37	30
Mesozoic.....	31	22
Tertiary.....	38	13
Recent.....	48	-----

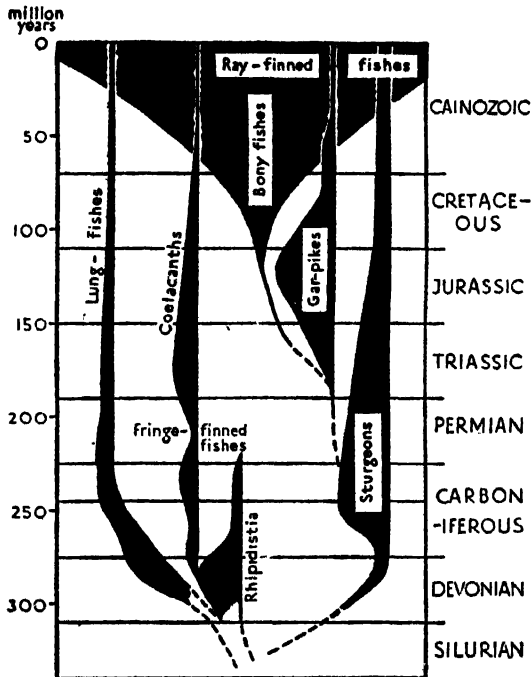


FIGURE 8.—The evolution of the true fishes correlated with the geological time scale. Based on a diagram by A. S. Romer.

To summarize, increase phases (often of the “explosive” type) in the evolution of genera, families, and orders lasted, so far as evidence goes, something like 15–100 million years, with a mean of about 50 or 60 million years.

In other words, the increase phase of evolution is of the same length [of the order of 50–60 million years (± 30)], irrespective of the systematic unit investigated. It is difficult to resist the temptation to speculate on the significance of this result. What it appears to mean is that the number of species steps involved in the evolution of new systematic categories is the same irrespective of the rank of the category. It takes no longer for a new order to evolve than for a new genus to appear.

If this is accepted as a valid inference from the material studied, then the difference between genera, families, orders, and classes must lie in the quality of the unit steps involved in their evolution. This is not a new idea,² though we have arrived at it from a new and unexpected direction.

What is meant by the statement that the quality of the steps decides the systematic category which is evolving, is easy to illustrate but difficult to formulate. A good example is the evolution of the jaws of the fishes from gill arches. This is an extraordinarily interesting case of change of function of an organ. Its real significance, however, is that this change provided the fishes with a decided advantage over their environment. It opened up new and better food supplies and, as Sewertzoff expresses it, "increased the general life-intensity of these animals." A biting-mouth skeleton is important also as an offensive and defensive weapon. It is, I think, sufficiently evident that this particular change of function was full of evolutionary potentialities. Applying Sewertzoff's terminology, such changes may be called *aromorphs*.

On the other hand, if one considers the extreme adaptation of a leaf insect (*Phyllium*), one finds that it has—to use Sewertzoff's phraseology—led to a decrease in the life-intensity of the animal. No new food supplies have been made available by the process of adaptation, and its evolutionary potentialities are nil. This type of adaptation is typical of the lower systematic categories.

There is another interesting feature that emerges from the chronological treatment of evolution. It is that there appears to be no correlation between fast rates of species evolution with groups having a rapid succession of generations. Elephants are among the most slowly breeding animals known and yet their rate of evolution was the fastest so far found. On the other hand, *Drosophila*, which, because of its rapid succession of generations, is so much used in experimental biology, is a genus 50 million years old. It appears therefore that a rapid succession of generations must not be taken as a substitute for long periods of time. It is indeed surprising to find that the number of generations is not the only factor ruling the rate of change in evolution and that this change is in a vague way correlated with absolute time. Does this perhaps mean that external, environmental factors are influencing evolution over very long periods of time? I am unable to answer this question, or to offer any other explanation.

I hope I have been able to show that a study of the chronology of evolution is well worth the effort. The suggestions made here must

²This has been put forward in different forms, for instance, by G. G. Simpson and R. Goldschmidt.

not be taken as final results. For the time being the material is still too scanty to make generalizations sufficiently safe. Some of the time rates, however, have been found by several workers independently, and some of the rules—if one be allowed to use this term—have been deduced by more than one worker.

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(Some diagrams shown in the discourse are figured in this article, and acknowledgments are due to the editor of *Discovery* for permitting their reproduction.)

MORE ABOUT ANIMAL BEHAVIOR

BY ERNEST P. WALKER

Assistant Director, National Zoological Park

[With 16 plates]

INTRODUCTION

The scope of the subject "animal behavior" is almost unlimited, for every species has its own particular pattern of behavior and the individuals of the species show many variations even from that pattern, so that the subject could really be made an exhaustive study for each and every species. Although psychologists have made extensive studies of human behavior, actually they have merely made a good beginning. Glimpses of animal behavior and some conception of how behavior patterns may have developed frequently help in explaining human behavior and human reactions, for our reactions are the result of a long series of experiences of trial and error and elimination by natural causes just as has been the case with those of other animals. Similar causes have brought about similar reactions in many instances, and different causes and environment have developed different reactions; there is, therefore, a remarkable diversity of behavior pattern among the different kinds of animals that live under many different conditions. Those that have not been able to adjust themselves to their environment have become extinct and are usually known only by their fossil remains; those that could adapt themselves and multiply are the forms that have survived to the present day.

The activities in an animal's life are essentially the same as the basic activities of humans. Individuals must survive, and to do so they must be able to avoid enemies, to obtain food and shelter; and for the species to survive, the individuals must reproduce and the young must be given an opportunity to start their own struggles for survival.

No doubt everyone who has observed animals closely has seen them do many things that could not be explained in the light of our experiences and practices. However, we must judge and interpret the

¹ An earlier article by the same author, under the title "Animal Behavior," appeared in the *Annual Report of the Smithsonian Institution* for 1940, pp. 271-312, 18 pls. As the first paper has been out of print for several years, some of the same ideas and examples contained in it are incorporated in the present paper, although not as exact quotations.

actions of animals in the light of the lives they normally lead in the wild. If we are well enough informed as to the conditions under which they live and their mode of life, we can often understand actions that would otherwise be incomprehensible or aimless to us. I do not believe that animals do any more aimless things than humans. On the contrary, I am often impressed by the direct and efficient manner in which they carry on the work of their lives.

The habits of animals are so intimately associated with and governed by their structure that one who is somewhat familiar with either the habits or the structure can often make rather close deductions from one regarding the other.

Every habit or type of behavior that has been developed because it helps the animal in its life is, of course, a special trait. Some are so little known that attention might be focused upon them and consideration given to the manner in which they benefit the animal. To understand the animals best, we must realize that merely because we cannot perform a given act does not mean that an animal cannot do it. For example, the sense of smell in most humans is so undeveloped that we cannot trail another animal by scent, as we know many animals do. Also, our hearing is so dull we cannot detect sounds that we know many other animals hear. Likewise, other senses of animals are probably so much more keenly developed than ours that they receive impressions or information of which we know little or nothing. For example, some animals give off vibrations that other animals are able to detect; the presence of a warm live body can be detected by certain snakes at distances of several feet even though their eyes and nostrils are not functioning; and apparently impressions are received by insects through their antennae and by fish through their lateral lines.

How individual animals acquire their behavior patterns is a fascinating field for study. Some actions are apparently taught to the young by the parents; some are learned by the young by observing others of their kind; some are learned by the trial and error system, or as we know it, "by bitter experience"; and some come to the animal by instinct; that is, the animal reacts in a certain way (usually the right way) under certain circumstances without previously having had an opportunity to learn consciously to act in that manner under those circumstances. How such reactions develop is explained by various theories and is a separate study.

ECOLOGY, STRUCTURE, AND HABITS

Ecologists refer to an animal as occupying an ecological niche, that is, the main activities of the animal take place within a certain type of habitat. It may live entirely within the water, on or under the ground, or almost entirely on trees, or combinations of any of these,

and its food is definitely limited by the products that it can obtain in the habitat which it occupies. Animals that do not use the same food or are not antagonistic, because one does not prey upon the other, can occupy the same areas or overlapping areas, so that ecological niches do not have definite, clearly defined boundaries, but are rather areas or space spheres of activity having also a time component. The structure of the animal to a large extent governs the type of ecological niche that it may occupy, since through evolution the animal's form has been modified to adapt it to the type of ecological niche that has been available to its long line of ancestors down to itself. Thus we can to some extent explain and understand the great variety of forms of animal life.

We might consider two little creatures of approximately the same size which occupy different ecological niches and are very different in structure, and see how they fit into their respective spheres. These are golden hamsters (*Mesocricetus auratus*) and "flying" squirrels (*Glaucomys volans*).

The golden hamster of Syria averages about 4 ounces in weight, with a maximum of about 8 ounces. It is a stout-bodied, short-necked, short-armed, and short-legged little mammal with short fingers and toes and a tail only about half an inch in length. It has very large cheek pouches that open inside the lips and extend far back of the shoulders, in which it can carry surprising loads of food or nest material. It is rich golden-reddish brown above and white beneath, with white hands and feet. The little creature is an inhabitant of an arid, rocky region where it lives mainly among rocks or in burrows in the ground around the rocks. Syria's climatic conditions result in a scarcity of food material for such little creatures for long periods of time; therefore, the storage of food is necessary and the cheek pouches are of great value in carrying food to its burrow or den. It works industriously at this, apparently the only limit to the amount of food it carries being determined by the amount that is available.

They are relatively slow-moving, clumsy little creatures in comparison with many other animals that we know, but are obviously well adapted to leading their lives in an efficient manner in their habitat. Their movements remind one of military tanks in that they are slow, ponderous, and persistent. There is nothing sprightly or agile about them, but if they want to go in a certain direction or up a certain surface they keep at it so persistently that frequently they succeed, and they can wedge themselves through surprisingly small crevices. They display remarkable persistence and determination to get into crevices that would seem to be so small and uncomfortable as not to be attractive to them.

The mouths of rodents are definitely on the underpart of the head and back of the nose, making it difficult for them to cut upward when

in their normal position. The animals solve this problem very readily, however, by throwing themselves on the back or side and cutting upward with their teeth. A picture of such an effort is shown in which my "Shehammy" has thrown herself on her back and is trying to cut upward on the lower edge of a door so that she can squeeze through the crack between it and the floor (pl. 1, fig. 1). This aperture was only seven-eighths of an inch high and, when she tried to force her way through it standing on her feet, she was much too thick and her body was much too tense, but in the inverted position she extended her arms forward so that she was able to get a grasp on the lower edge of the door and pull herself through the crevice, which she did repeatedly. This "hammy," one of my pets, did it regularly, and I have seen other rodents do it occasionally.

Frequently one of my golden hamsters, when permitted to run about my study in the evening, would clamber up in the crack between a bookcase and the wall a foot or more above the floor and stay there for a considerable time. She usually rested by bracing her feet against the wall and her back against the bookcase and apparently was content to stay in that position. This suggests to me that these animals adopt such a position as a means of being comfortable in fissures between the rocks among which they live.

When hamsters want to get down from an elevation that they have reached, they apparently do not think of jumping down even a few inches, but lower themselves as far as possible with the hind feet, sustaining themselves by the top of the hind feet, which are bent at the ankle. Next they release one foot and then the other and fall head downward, usually landing on their noses, but sometimes on their backs (pl. 2). They then sit up, sneeze, rub their noses, and go about their business. It will be noted that they do not utilize their hind claws or toes which are too small to be effective. This method, while probably a relatively inefficient action, has persisted because it is not seriously harmful in the circumstances under which they live, and is the best they can do with their short fingers and toes which are not of much use to them for such descents.

At night, when foraging for food, hamsters apparently spend very little time eating, preferring to fill their pouches, take the load of food home, and return for more (pl. 1, fig. 2). In this way they gather food when it is available and eat at leisure in their nests without being exposed to danger. During the daytime, their sleeping period, they frequently wake up and eat, probably consuming much more food at this time than during the night when they are actively foraging, grooming, exploring, or visiting their neighbors.

When "hammies" are away from their homes or other shelter and there is a sudden alarm, they dash for shelter with surprising speed for little folk with short legs but if they are touched or attacked before

they can get away, they throw themselves on their backs incredibly quickly and are prepared to fight savagely with their sharp, fairly strong teeth and tiny claws. If they are in their nests, they pay little attention to outside disturbances, at most sniffing from just inside the doorway.

Baby "hammies" arrive in litters of as many as 17, tiny, blind, naked, pink, helpless little fellows that lie on their backs and nurse while mother "hammy" hovers over them to keep them warm in the snug cup-shaped nest of fibers she has constructed in a remote portion of the burrow or den. The little ones grow very rapidly, and by the thirteenth day they have a good coat of fur, are eating solid food, and begin wandering about in the burrow, den, or cage. Even though their eyes are not yet open, they find their way back to the nest if mother has not detected their absence and carried them home. By the fifteenth day their eyes are open, and by the seventy-third day they produce babies of their own. They bear large families in rapid succession but cease to breed regularly when about 1 year old, and the life span is short (probably a maximum of about 3 years). There is a high mortality rate, probably throughout life.

The structure and lives of the flying squirrels (*Glaucomys volans*) of North America are in marked contrast to those of the hamster. Flying squirrels weigh about 3 ounces, have slender bodies, long, slender, strong arms, fingers, legs, and toes with fairly long, curved claws, and a rather long tail. The skin of the body is much larger than is necessary to enclose the delicate little form and is extended outward along the side as hair-covered membrane indistinguishable from the skin of the body. This skin reaches down to the wrists and ankles, so their outline is almost square when the little creatures put their arms forward and out and their legs back and out as they do while gliding through the air. This adaptation more than doubles the area of the upper and lower surfaces as it appears when the animals are at rest. In keeping with this form, the hairs of the sides of the tail are long, and closely set, and project at almost right angles, whereas those of the upper and lower surfaces are very short and lie close to the bone of the tail, so that the tail is, in cross section, almost like a feather. All these are modifications for life in an entirely different habitat from that of the hamster.

Flying squirrels live among the trees, generally making their nests in hollow limbs, old woodpecker holes, or other shelters high above the ground. They are strictly nocturnal, having very large eyes adapted to admitting the maximum light available. They are not limited in their movements to climbing up and down the trees or to mere leaping between objects, for their remarkable form gives them power to glide long distances. To do this they seek an elevated point, leap out into space and spread their arms and legs so that they take

on the form of miniature gliders (pl. 4, fig. 1). When approaching a landing, which they generally try to make on a tree or other object not on the ground, they swing slightly upward to check the glide and bring their long arms and legs forward as shock absorbers (pl. 4, fig. 2). Instantly upon alighting they dart around to the other side of the tree or limb, which is probably a provision to escape any enemy that might be following them.

Before flying squirrels take off on a glide they almost invariably sway the head and body as far as possible first to one side then the other, repeated several times, and often raise as high as they can stand and crouch as low as possible. This is probably a sort of range finding by triangulation.

They feed very largely on nuts and acorns which they gather and store in their nests and probably in almost any location in the forest in which they can find a cavity that is large enough to hold a nut securely. I assume this from the fact that my pets regularly place nuts at many places about the house other than in their nest box. They particularly selected the top of the window, the medicine cabinet in the bathroom, my hand, my pockets, inside my collar, and even the depression between my arm and body when I have my arm close to my body. When placing nuts, they have an interesting habit of trying to make them secure wherever they are leaving them. They force them into the crevice or onto the surface where they are leaving them, then tap them three or four times with their front teeth. This suggests that they probably similarly try to wedge the nuts in cracks in the bark or slight depressions on the tops of tree limbs in the wild.

In addition to nuts and seeds, they eat some fruits, berries, and insects. My pets eat mealworms, grasshoppers, and small bits of meat in moderation.

"Glauckies" (short for their scientific name) are very hesitant about going down to the ground, feeling much more at home leaping about in the trees, gliding from place to place; however, they will go down on occasion. When they do so, they are plainly not at home and run with the arms and legs extended so as to hold the body as high above the ground as possible, the gliding membrane being pulled upward close to the body so that a very peculiar effect is produced.

Instead of sleeping soundly and ignoring disturbances in their neighborhood, as do the hammies and many other burrowing creatures who know they are safest in their dens, the flying squirrels sleep lightly and at the least disturbance in their neighborhood they peer out or dash away.

"Glauckies" are born in families of two to six pink, helpless little ones, with the gliding membranes plainly evident. They develop

slowly, are not well clothed in fur until about the twenty-eighth day, and continue nursing until about the fifty-sixth day. In recognition of the dangers of an active life in trees, they, like young tree squirrels (*Sciurus*), start out exploring near the nest with great caution, and venture farther and take more chances only as they gain strength, experience, and confidence. Their gestation period is about 60 days and young are born when the parents are about 1 year old.

These brief descriptions of the widely different hamsters and flying squirrels, which inhabit very different ecological niches, give a glimpse of the specialization among animals which enables them to survive and to lead their lives under diverse conditions.

Giraffes (*Giraffa*) have developed such a high degree of specialization that they are able to fill an ecological niche without competition with other mammals except in those portions of their range which overlap that of the elephants. Much of the food of the giraffe is taken from the upper portions of shrubs or from the lower branches of trees far above the reach of most mammals. In addition to its long legs and very long neck, the giraffe has elongate, mobile lips and can extend its tongue several inches to help it gather in leaves and twigs.

The moles (*Scalopus* and other genera), which burrow in the earth, are blind, have exceedingly short forelimbs, with nose and tail very sensitive to touch, large, powerful hands armed with long, strong claws, and very strong muscles in the fore part of the body, particularly those associated with the arms. The fur is very soft and short and will lie in any direction; thus it does not impede the mole when it desires to run backward in its burrow, which it often does. Moles feed on earthworms, grubs, and other small animal life they catch in the earth. (See pl. 5, fig. 2.)

In marked contrast are the gibbons (*Hylobates* and *Symphalangus*), highly specialized members of the primate or monkey group. Their arms are exceedingly long and powerful, with elongate hands and four strong fingers, the thumb being small and situated far back on the hand. The legs are rather long, and the feet are better fitted for grasping than are the hands. The body is small. These adaptations enable gibbons to be the most expert of all mammals in swinging by their arms through the forest from branch to branch and even from tree to tree. In this process the hands are used as hooks, the thumb taking no part in grasping. Since the hands are usually occupied when traveling through the trees, gibbons carry objects such as food or branches by grasping them with the feet. The same method of carrying objects is used by chimpanzees (*Pan*) and orangutangs (*Pongo*).

Whereas the gibbons, chimpanzees, gorillas (*Gorilla*), and orangutangs lack tails, the spider monkeys (*Ateles*) of Central and South

America possess long, prehensile tails which they use in many ways, especially to hang by or to use as a supplementary hand in steadying themselves. In the picture (pl. 11) it will be seen that one of the animals is using its tail to hold itself while it leans far forward. On one occasion I saw seven spider monkeys in this group leaning forward, held by their tails, watching for the door to open so they could go into the house for their afternoon meal.

Some rodents have large, powerful incisor teeth that protrude much more than those of the majority of rodents, and one naturally surmises that this trait is associated with some habit peculiar to them, which indeed it is. The animals possessing such teeth use them in burrowing; that is, they cut away the earth, remove small stones, and cut roots, thus performing most of the functions that the powerful hands of the mole perform and, in addition, do the cutting work which the mole's hands cannot do. Some other rodents, and many of the insectivores also, have projecting incisor teeth, but these are relatively small and slender and are obviously not suitable for such heavy work as digging, moving small stones, or cutting. These are used as forceps for the picking up of food, which consists mainly of small fish, insects, or worms.

Such animals as the kangaroos (*Macropus*), the kangaroo rats (*Dipodomys*), the African spring hare or spring hase (*Pedetes*), the jerboas (*Alactaga*, *Scarturus*, *Salpingotus*) and others have large, long, powerful hind legs, relatively small, weak, short forelegs, and long tails which are either tufted with long hairs near the tip or are rather heavy, often very thick near the base (pl. 5, fig. 1). These animals are leapers and use the hind legs almost exclusively in propulsion. The tail is a balancing member; it also acts as a tripod leg in some forms.

The types of leaps of different animals vary greatly. One interesting difference is the contrast between the leap of the flying squirrel, an animal that leaps directly toward its objective with a very flat trajectory, often planning to land below its target and then climb up to it, and the leap of the tarsier (*Tarsius*) which has a very high trajectory and lands the leaper at its objective. After becoming accustomed to photographing the leaps of flying squirrels, I tried photographing tarsiers leaping and aimed my camera as I would for the squirrels. With the pronounced leap upward of the tarsier, I at first caught only the tail and hind portion of the animal in the upper portion of the picture. After a few such experiences I learned the difference in their leaps and corrected my aim accordingly.

The list of such highly specialized forms could be expanded indefinitely to include representatives of all groups of animal life, for every animal is specialized to lead a certain type of life.

CLEANLINESS

Almost all animals are fastidiously cleanly about their persons and their homes. Because of the fact that many animals live on or in the ground or on trees or other surfaces that frequently are dirty according to our standards, we often erroneously consider the animals to be uncleanly. As a matter of fact, practically every animal takes great pains to avoid soiling its coat, and when it does unavoidably become soiled, the animal at the first opportunity painstakingly cleans itself by shaking, rolling in the sand, washing in water, or licking itself. Even those pests, the common Norway rat, roof rat, and house mouse, which have found that they can obtain food and shelter in man's filthy surroundings, endeavor to keep themselves clean. If they are observed when not alarmed, it will be seen that they carefully pick their way through their surroundings in an effort to avoid soiling themselves, and after they have finished their exploration they will invariably be seen to groom carefully. If one will part the fur of small mammals it will be seen that the skin is generally immaculately clean.

A star-nosed mole (*Condylura cristata*) that I am keeping as a pet comes out of the ground, goes into a dish of water and at once begins grooming. In a few minutes it has washed thoroughly.

Animals have developed many ways for keeping themselves and their nests clean. Apparently flying squirrels rarely void excreta during their entire sleeping period, which may be as much as 16 hours. Obviously they wish to keep the inside of the tree or other nest location clean, so wait until they go out at night when they can see clearly and there is a minimum of danger from outside enemies. Many of the burrowing mammals have little toilet rooms that open off of the main burrow where they deposit their excrement, thus keeping the main burrow clean. Young North American opossums (*Didelphis virginiana*) of an age to be in the pouch or still be clinging to their mother apparently do not release their excretion unless they are stroked on the lower abdominal region. This is probably a provision for keeping the pouch clean until such time as the mother is ready to clean the little ones.

POSTURES

The new-born babies of many of the small mammals naturally lie on their backs. This leaves them in the proper position for nursing when the mother hovers over them, protecting them, hiding them, and keeping them warm.

Most hoofed animals do not voluntarily sit on their haunches. A horse assumes this position briefly when getting up, but this does not constitute true sitting. The exceptions to the rule are the tapirs,

which frequently sit on their haunches with the forefeet supporting the front part of the body (pl. 14, fig. 2).

A position that would appear to us to be uncomfortable is regularly adopted by flying squirrels, which normally live in hollow trees. The body hangs in a vertical position, either head up or head down, suspended by the fingers or the toes, most of the load actually being on the fingernails or the toenails (pl. 3, fig. 1). They sleep in such poses at least a portion of the time. The hanging position is probably assumed as the result of having accommodated themselves to situations where there is no satisfactory ledge or bottom in the den, so that a tree cavity that would otherwise be unsuitable can be utilized by clinging to its rough surfaces. However, they now take this pose freely even when comfortable nests or rests are available. Of course, they also take other positions such as curled up in a ball or lying on the side or the back.

The inverted position so often used by sloths (*Choloepus*, *Bradypus*, and *Scaevophus*), wherein they hang beneath a limb, is well known and is entirely suitable for their purposes. Bats generally hang head downward.

HOMING INSTINCT

When an animal has become established at a given location, it almost invariably develops a strong attachment for its home even though such home does not provide entirely satisfactory quarters. Almost every animal has a rather definite area in which it lives its entire life, and it rarely leaves this range except when forced to do so by very unusual circumstances. This is commonly shown when captive animals escape, for they usually remain nearby for some time and frequently go back into the cages if they are able to do so. People who are familiar with animals regularly take advantage of this trait by leaving the cage door open, refraining from frightening the animal, and placing food in the cage or nearby until the animal is recaptured.

On one occasion I was keeping a specimen of the least short-tailed shrew (*Cryptotis parva*) in a jardiniere. I had observed it trying to leap out, but it is not adapted to leaping and was apparently unable to reach the top. After a few days I discovered that it had escaped during the night probably by superior jumping gained by persistent exercise. It was so tiny that it was useless to search for it in the house, so I waited until evening and then placed the jardiniere on the floor almost directly below the place at which it had been standing on my desk. I crumpled around it an old blanket so that it formed a ramp or runway from the floor up to the top of the jardiniere. I then mashed a mealworm and dragged particles of it in a trail on the blanket from where it touched the floor to the top of the jardiniere. Within a couple of hours the little fellow was back in his home.

Plainly he had come to recognize the jardiniere as home and was glad to get back to it when it was made possible for him to do so.

Remarkable developments of the trait of returning to the home range are shown by carrier pigeons (*Columba*), and birds, mammals, and fish that migrate.

SELF-PRESERVATION

Humans ordinarily give little thought to the matter of self-preservation, although it becomes a vital subject during wartime. Among other animals it is ever foremost. In its broadest aspects self-preservation involves not only active and passive resistance to enemies, but also the ability to obtain food and shelter. Humans have recently had brought to their attention the fact that they, like other animals, must either be prepared to defend themselves or run away when an aggressor attacks or threatens. If there is no place to which they can escape, or if they cannot successfully fight off their enemy, they have only the alternatives of being subjugated and made slaves, as sometimes happens among humans, or of being destroyed, which in the case of animals may mean being devoured.

There are very few animals that are aggressive to the extent of trying to drive away or subjugate their neighbors merely for the pleasure of the victory. Ordinarily, they will start a fight only when it is necessary to obtain food, shelter, or a mate.

The methods used by animals to avoid, escape, or defeat an enemy are almost as numerous as the species of animals, for the individuals of every species employ one or more methods. All are interesting and some are very remarkable.

The seeking of shelter is the most common of passive defensive measures and is practiced to a greater or less degree by all animals. Some go into burrows in the ground, crevices in rocks, or holes in trees, while some of the larger ones retreat into dense jungles or forests.

"Freezing," the act of remaining motionless, is extensively employed, as at the first intimation of danger almost every animal ceases practically all movement. Since an object which is very conspicuous when moving is readily overlooked when stationary, "freezing" is a highly successful means of avoiding detection by enemies. Even those that depend mainly on their ability to scent their prey may have difficulty locating it if they cannot see it.

Rabbits and hares (*Leporidae*), quail (*Colinus*), and grouse (*Tetraonidae*), when perfectly still in their native haunts, are very difficult to see, and often will not move unless one almost steps on them. This method of escape is applicable in almost any type of surrounding, even on seemingly barren plains or expanses of snow. It is most effective, of course, if the color pattern of the animal is such that it

harmonizes and blends with the surroundings or if the outline of the animal is obliterated by some type of camouflage. Most animals are so colored that they blend perfectly with their surroundings, some, such as the ptarmigan (*Lagopus*), certain hares (*Lepus*), and weasels or ermine (*Mustela*), even changing to white in winter to blend with the snow.

Among insects, camouflage and mimicry have been developed to a high degree of perfection in many species. Some resemble their natural surroundings so closely that they are difficult to distinguish even though one is looking directly at them. Resemblance to dead or green leaves or stems is the most common camouflage, the pattern and form of the insect being modified to a strikingly perfect imitation of the color and form of those parts of the plant on which the insect usually lives. In the type of specialization known as mimicry, one species of insect very closely resembles and usually behaves like another which is distasteful or dangerous to animals. By this resemblance the imitator is often let alone by an animal that mistakes it for the undesirable insect which it resembles.

When it is not possible to avoid an enemy, some animals use a more or less passive method which is well illustrated by the armadillos (*Dasypus*, *Tolypeutes*, and related genera) which roll themselves into a ball, completely protecting the feet, tail, and head within the armor plate of the body (pl. 6, figs. 1 and 2). This method effectively baffles many animals that would ordinarily devour them, and when the would-be attacker becomes discouraged and leaves, the armadillo unrolls itself and goes about its business. Another method is the feigning of death, which is well illustrated by the American opossum which, when alarmed, falls on its side with the mouth partially opened and appears so limp and inert that it is often left for dead by animals that would vigorously attack if they surmised the animal to be alive. Apparently opossums are unpalatable to many animals, so that this means of protection is very effective. When danger ceases to threaten, the opossum gradually resumes activity, but if the attacker is merely waiting nearby and makes a movement, the opossum will usually again go into its death-feigning act. It is supposed that this behavior is a type of fainting induced by fright and is perhaps not actually under the control of the animal. When the hog-nosed snake of the eastern United States, frequently called spreading adder (*Heterodon*), feels itself in danger, it feigns death, throws itself on its back, and assumes various grotesque poses if it is seriously aggravated. It does not, however, do this unless the annoyance is great and continued. Many insects feign death when a disturbance occurs in their vicinity. This is illustrated by the many beetles that inhabit low shrubbery, which drop from their elevated locations to the ground and remain quiet or quickly take refuge in a more protected location.

One of the most remarkable modifications of feigning death of which I have heard was witnessed and described to me as follows by John N. Hamlet, of the United States Fish and Wildlife Service:

Three of us recently saw a Cooper's hawk (*Accipiter cooperi*) chase a spotted sandpiper (*Actitis macularia*). The piper dropped into the water and stayed under for several seconds. The Cooper's lit on the stream edge a few yards down the stream. The sandpiper came to the surface and floated down the stream with its wings open flat on the water and its neck stretched out. It passed within 3 feet of the hawk who gave it no more than a casual glance. The piper floated down stream about 20 yards and took off and disappeared.

The live sandpiper drifted close by the hawk but was not recognized because it was not moving in its usual pose. This is a choice example of the effectiveness of "freezing" and assuming an unusual pose. Mr. Hamlet has witnessed similar action by sandpipers on two other occasions.

Bluff is another effective defense that is employed by many animals. Its best form is for the animal to face its enemy in a pose not usually assumed by it and that makes it appear as large as possible, ferocious, and threatening. Many, if not all, of the owls (*Strigiformes*) bluff by crouching low, spreading their wings at almost right angles to the body and ruffling the body feathers until the bird appears several times larger than it really is. The bittern does likewise, and most mammals bluff to some degree. A good example is the dwarf weasel (*Mustela rixosa campestris*), only about the size of a cigar, who stands his ground, opens his mouth wide, barks, and even attacks if need be, although its teeth and jaws are so small it can scarcely break the skin of one's hand. The domestic cat's (*Felis cattus*) high-arched back, bushed-out tail, and wide-open, snarling mouth present a good example, and many of us have witnessed the hesitation of a dog suddenly confronted by such an attitude. Often this hesitation gives the cat an opportunity to escape without having to fight.

Fighting for mates is definitely beneficial to the species, for by nature's law of the survival of the fittest, which must prevail through all species, only those survive that are best able to take care of themselves. This, taken in its broadest sense, includes not only physical strength but mental alertness and adaptability to varying and new conditions. Males that are physical weaklings and would not father vigorous offspring are ordinarily vanquished in encounters for mates and therefore leave no progeny. By this process nature has consistently eliminated the unfit and has improved each of the species. The occasional maiming of individuals in their conflicts is not in itself injurious to the species, as such mutilations are not inherited and, if the parent was vigorous, the progeny stand excellent chances of being vigorous even though the parent may have been injured in some of its conflicts.

Among animals that live in colonies or in herds, conflicts are generally rare except among males that are fighting to determine who shall be master of the herd, as in the case of bison. However, on one occasion I witnessed a definite fight in a prairie dog (*Cynomys*) colony. In this case the aggressor was outside of the burrow and trying to keep another one in the burrow and, at the same time, to fill the burrow with dirt to bury him. Several others were within a few feet watching the proceedings but taking no part in it although it was obvious that they sympathized with the "underdog." Whenever the one that was in the burrow would attempt to come out, the one that was outside would try to bite and scratch him, and, when he had him forced back into the burrow, would scratch and push earth into the entrance. Finally, after perhaps 20 minutes, he lost interest and left. The bystanders almost immediately went to the burrow, greeted and apparently sympathized with the one that had been attacked, and in a few minutes the normal life of the colony had been resumed. This method of fighting by trying to imprison the victim is also used by prairie dogs in closing the entrance to the burrow which a snake has entered.

ADAPTABILITY

The readiness with which animals accept approaches or friendliness of man varies greatly. Some seem to be so thoroughly imbued with caution and suspicion of man's intentions that they can be tamed only with the greatest of effort. Others respond almost immediately to handling and friendly treatment. Examples of the latter are the gray foxes of the United States (*Urocyon*) which tame very readily and in marked contrast to the general wariness and slow taming of the red foxes (*Vulpes*). The beaver (*Castor*) is another animal that tames easily, sometimes merely a few hours of kind treatment being sufficient to win its confidence. Young hair seals (*Phoca*) also tame almost immediately when captured. Usually they seem to have no fear when picked up, looking to their captors as friends and becoming affectionate pets, sometimes swimming after a boat that is leaving them behind after its occupants have picked them up and petted them briefly.

Penguins are fearless and very curious as to visitors on land or on the ice or snow where they normally have few or no enemies, but in the water they are cautious as there they are accustomed to watching for enemies such as killer whales (*Orca*), sea leopards (*Hydrurga*), and large fish.

Another phase of the adaptability of animals is the degree to which wild animals can survive where man has established himself. Most of them appear to have no fear of man's presence and his activities so long as they are not actually molested and their haunts and food

supply are not destroyed. We can see numerous examples of animals that have gone ahead fairly successfully with their lives when man has not interfered too much with conditions essential for them to live.

Another group consists of animals that thrive in close proximity to man and either become a part of man's household and receive his direct aid in their existence, or adapt themselves to the conditions that man provides and obtain food and shelter in spite of his utmost efforts to control them. In this group are the Old World rats (*Rattus*) and mice (*Mus*) that have become established almost throughout the world wherever man has made settlements. Other examples are the European house sparrow (*Passer domesticus*), commonly called English sparrow in the United States, and the European starling (*Sturnus vulgaris*) both of which have become firmly and widely established in North America. These two birds, like the rats and mice, have become pests in some regions where they have adapted themselves to a remarkable degree and have become very plentiful. They have found sufficient food and shelter around man's activities so that they have thrived where other less adaptable forms have not been able to survive. Indeed, in many cases they fight the native birds and take over the ecological niches normally occupied by the local birds that are less adaptable and aggressive and have not been successful in defending their territory.

It is sometimes said that there is a third group of animals comprising those that cannot tolerate proximity to man but, if we study the problem, we usually find that man's activities so changed conditions essential to them for food or shelter that they could not survive, or else that man intentionally killed them off.

Most animals, if given to understand that man will not harm them, will become tame, and if man will feed them it is surprising how friendly even very wild kinds will become. I have a pet big brown bat (*Eptesicus fuscus*) that in a few days became so tame it would return to me after each of its flights about the room (pl. 13, fig. 2). Even when I awaken her she makes some effort to overcome her stupor and come into my hand to be warmed preliminary to taking her evening flights and receiving mealworms, of which she is very fond.²

Chipmunks (*Tamias*) that have been tame during the summer or fall, then go into partial or complete hibernation and are inactive for a period of from 5 to 6 months, come out in the springtime and resume their friendships and friendliness practically as though they have not been interrupted. One individual that came in the window onto my desk and was so tame that I took a picture of it while it was on my hand obtaining food, returned the following spring and re-

² In the Saturday Evening Post for February 4, 1950, is an account of further results of my studies of bats.

sumed our relationship where it had broken off with the beginning of bad weather the previous fall.

Another example of the confidence of wild creatures is the case of two flying squirrels that are greatly loved guests in our home. They have such fondness for both my wife and myself that they want to be with us at every opportunity, even to sleeping in our pockets. They leap to us as a means of quick locomotion and for the pleasure of the leap and glide (pl. 4, fig. 2). Their behaviour has been treated at some length in the National Geographic Magazine for May 1947, "Flying Squirrels, Nature's Gliders."

OBTAINING FOOD

The obtaining of food is an ever-present problem for all animals. With some it is apparently a very simple process; with others it brings into play the use of the special structures with which nature has provided them. The food-getting habits of practically every animal would make an interesting study, but only a few of the widely different methods can be mentioned here.

The peculiarly shaped bill of the flamingo (*Phoenicopterus*), which looks as though it had been broken in the middle and the tip bent downward, is used in an interesting manner. As will be seen from the picture (pl. 7, fig. 1), the bird extends its neck almost straight downward, which brings the upper portion of the bill closest to the ground. The edge of the bill then scrapes along the ground in very shallow water, and the lower mandible opens and closes rapidly. The water thus scooped into the mandible is strained between the fine laminations of the upper and lower mandibles and then discharged after the minute crustaceans on which the flamingo feeds have been strained out.

Relatives of the flamingo are the swans and other water fowl (Anatidae), many of which obtain their food in fairly shallow water. They eat a wide variety of plant and animal material such as seeds, green leaves, tubers, fleshy roots, mollusks, and crustaceans, and a few of them eat some fish. When the food is not too far below the surface of the water, they "tip up" so that they can extend the neck and head to the maximum distance below the surface (pl. 7, fig. 2). Others dive for their food.

Hérons (Ardeidae) feed mainly on small fish, frogs, and other animal life, which they obtain by standing practically motionless in the water and waiting for the unwary victim to come within reach. They suddenly extend their long necks to a surprising distance and catch the prey before it has a chance to dart away. They may stand in such a position for hours at a time waiting for their victims to approach.

A very different method of obtaining food is employed by the birds of prey (Falconiformes), which catch their victims by a quick swoop. An outstanding example of a bird that employs this method is the falcon (*Falco*), which while soaring or flying almost out of sight will detect a bird in flight, or a bird or small mammal on the ground, dive from thousands of feet at speeds of as much as 280 miles an hour with the wings almost folded but extended just enough to enable it to steer itself, and strike and carry off its victim in its talons. In these dives the speed of the bird is so great that a whistling sound is produced. On one occasion I heard the whistling and an instant later a half-grown chicken was struck within about 8 feet of where I was standing, the falcon having come down at about a 45° angle over my head. It scarcely seems possible that a bird can fly with such speed and accuracy as to overtake and capture a startled duck in the air, but the duck hawk (*Falco peregrinus anatum*) does this regularly, providing a thrilling demonstration of skill and dexterity. Hunting with falcons was a royal sport in the Old World for many centuries and then was almost discontinued in Europe. It continued in Asia and is now popular again in Europe and the United States, where many different kinds of birds of prey are being trained to capture game or lures and bring them to the trainer. Among the birds that have been so trained are the beautiful, dainty little sparrow hawk (*Falco sparverius*), Cooper's hawk (*Accipiter cooperi*), duck hawk, the prairie falcon (*Falco mexicanus*), golden eagle (*Aquila chrysaetos*), and even the barred owl (*Strix varia*).

Another and little-known method of obtaining food is practiced by the skimmers (*Rynchops nigra*), in which the lower mandible is considerably longer than the upper. Their regular practice in feeding is to fly so close over the water that the tip of the lower mandible is in the water, and when they come upon fish they merely lower themselves enough so that they can scoop up the fish.

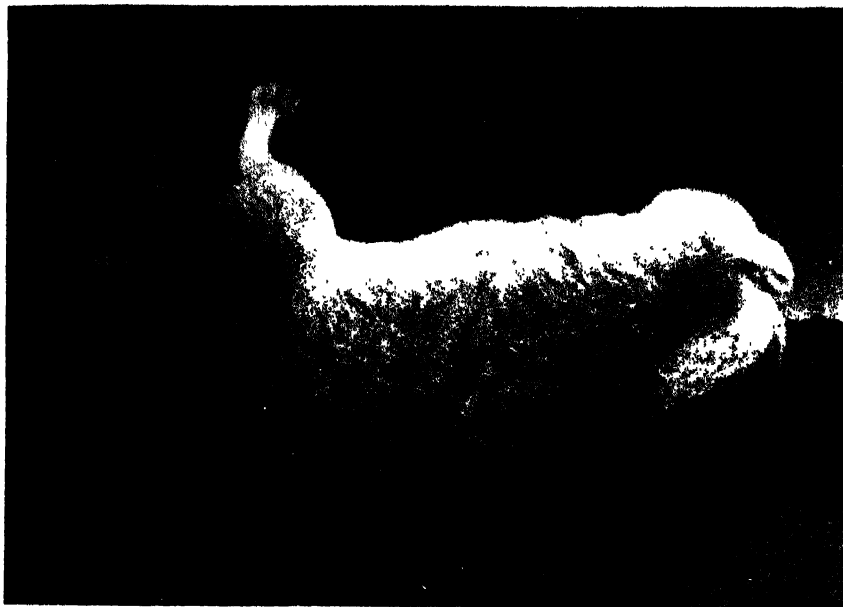
Practically all woodpeckers (Picidae) feed on insects, most of which they capture in their burrows in wood. These birds may often be seen going up or down trees, keeping the body often in a vertical position by grasping the trunk with the feet and leaning back on the stiff tail. Through their keen hearing they detect an insect under the bark or in the wood, and then proceed to cut away the bark or wood with their beaks until they approach close enough to the insect or worm so that they can draw it out of its burrow with their long-barbed tongues. The work of the woodpeckers in removing insects from the wood is far more beneficial than harmful, for if the insect is allowed to remain there it may do considerable damage, whereas the woodpecker ordinarily works only to excavate wood that has already been damaged by the insect, and by removing it prevents

further damage. The flickers (*Colaptes*), members of the woodpecker family, have found a less laborious method of obtaining a considerable portion of their food—they have learned to eat ants on the ground and have taken to feeding extensively on these and other insects in addition to what they get from the trees. The California woodpecker (*Balanosphyra formicivora bairdi*) and its relatives feed to some extent on acorns, which are very plentiful in many portions of their range, and they have adopted the practice of making holes in the bark of trees or in posts in which they place acorns for future use. Sometimes a trunk or limb of a tree or post will be studded with hundreds of acorns, each in its own separate setting which holds it securely with the end of the nut projecting slightly from the hole.

The night hawks (*Chordeiles*), whippoorwills (*Antrostomus*), swifts (*Chaetura*), swallows (*Hirundo*) and their relatives capture practically all their food in their very wide capacious mouths while flying. Some birds such as the tyrant flycatchers (Tyrannidae) and a few others have the habit of sitting on a perch that gives a good view of surrounding territory and watching for insects. As these come within range, they are captured in the air in a short flight by the bird, which then returns to its perch to watch for more. The hummingbirds (Trochilidae), as is well known, have a very long beak and tongue which they extend into flowers to feed on the nectar and insects that they find there. Other small birds known as honey creepers (Correbidae and Melithreptidae) have a long, sickle-shaped beak which they use in obtaining insects, nectar, and fruit pulp and juices.

Feeding habits among the mammals also vary widely. The langur and colobus monkeys (*Presbytis* and *Colobus*) feed mainly on the leaves of certain trees. Many of the bats, particularly the small ones (*Microchiroptera*), feed almost exclusively on insects that they capture in flight. Some forms are carnivorous, killing other bats and small birds and perhaps small mammals. Vampire and false vampire bats (*Desmodus* and *Diaemus*) lap blood that they obtain from warm-blooded animals by cutting off a very thin layer of the skin with their razorlike incisor teeth. Other very large bats with a wingspread of as much as 4 feet, which inhabit the Tropics, are known as fruit bats (*Pteropus* and related genera) because they feed largely on fruit. These bats frequently travel in considerable flocks and move to various regions from time to time to find food.

Most rodents eat mainly plant food such as seeds or nuts, leaves, stems, or roots of plants; many, however, also eat some insects and small amounts of meat. A few have developed highly specialized feeding habits together with specialized teeth and shape of jaws. These include the fish-eating rat of South America (*Ichthyomys*) and an insectivorous type (*Rhynchomys*) from Luzon Island in the Philippines. Nothing has been recorded regarding the habits of this animal,



1. GOLDEN HAMSTER (*MESOCRICETUS AURATUS*)

Lying on her back, she is trying to cut upward on the lower edge of a door. In this position she pulled herself through the $\frac{7}{8}$ -inch crack under the door.



2. GOLDEN HAMSTER (*MESOCRICETUS AURATUS*)

The cheek pouches are filled with seeds. The pouch is outlined by a white dotted line.



GOLDEN HAMSTER (*MESOCRICETUS AURATUS*), GETTING DOWN FROM A SHELF 30 INCHES ABOVE THE FLOOR

Left, lowering herself over the edge; center, lowered to full length of legs; upper surfaces of feet are holding her; right, one foot released and ready to release the other foot and drop.



1. EASTERN FLYING SQUIRREL (*GLAUCOMYS VOLANS*)

Hanging head downward is one of its favorite positions while eating.



2. EASTERN FLYING SQUIRREL (*GLAUCOMYS VOLANS*)

The flattened tail, long, strong fingers and toes, large eyes, and edge of the gliding membrane are clearly shown.

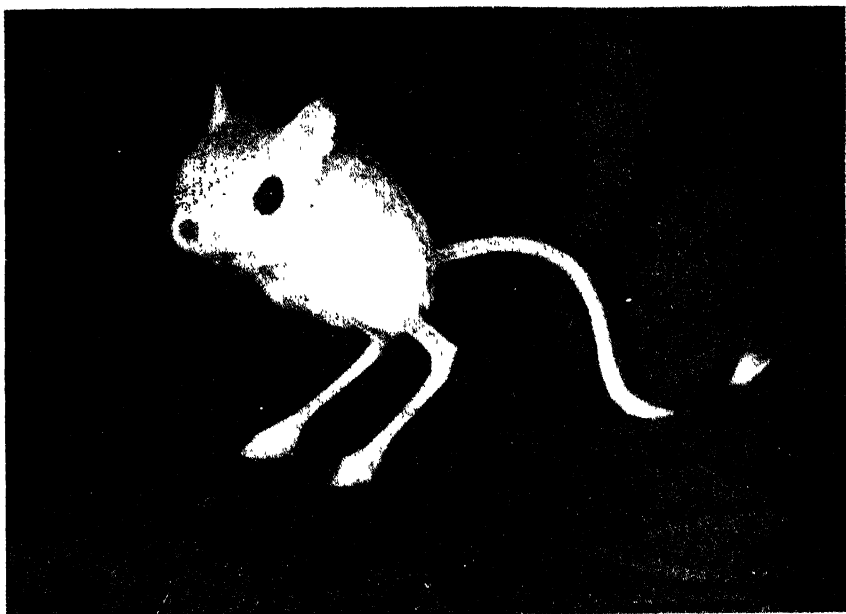


1 EASTERN FLYING SQUIRREL (*GLAUCOMYS VOLANS*)
A glide as seen from beneath and to one side.



2. EASTERN FLYING SQUIRREL (*GLAUCOMYS VOLANS*)
Preparing to alight from a glide.

The two pictures on this plate were taken with the electronic flash which operates at about 1/5000 of a second.



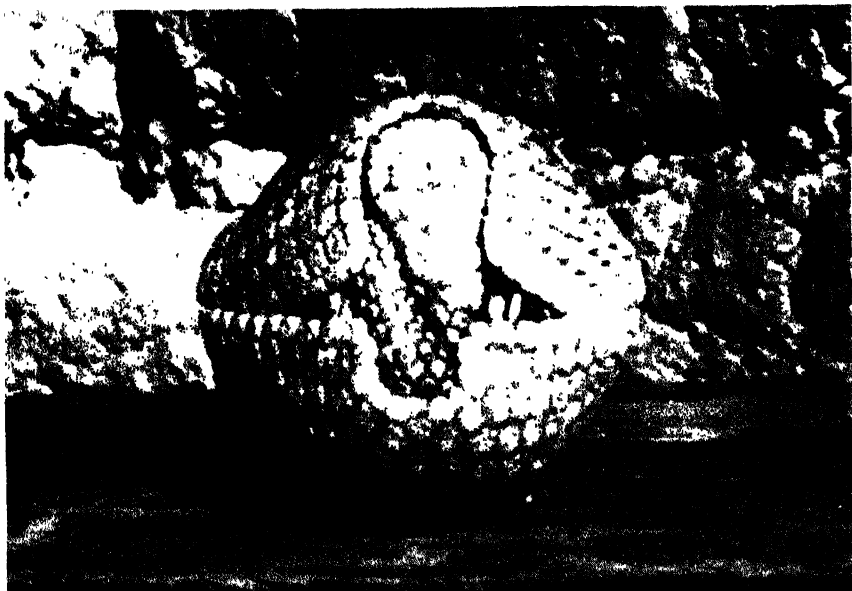
1 EGYPTIAN JERBOA (*JACULUS JACULUS*)

A characteristic pose, with the very small arms and hands held close to the throat. The hairy pads beneath the feet are protection against hot sand and the abrasive action of rough surfaces.



2. TOWNSEND'S MOLE (*SCAPANUS TOWNSENDII*) (MUSEUM SKIN)

Showing the broad, powerful forefeet with large, straight claws for digging; the long, sensitive, mobile snout; short, sensitive tail; and dense, soft, short, plush-like fur.



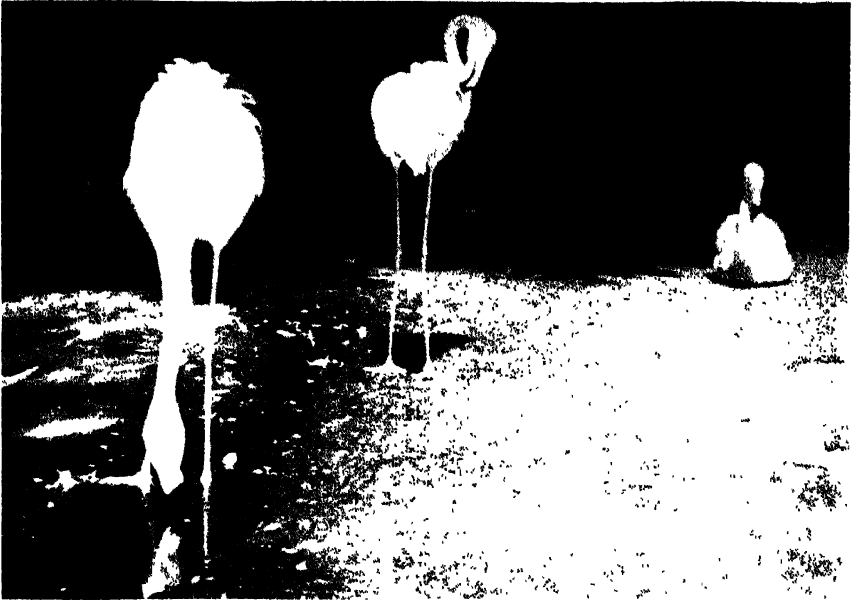
1. THREE-BANDED ARMADILLO (*TOLYPEUTES TRICINCTUS*)

Rolled up as a protection against enemies. The top of the head is the large inset portion in the front of the shell; the tail is lying along side of the head. (Photograph by João Moojen)



2. THE BACK OF THE SAME ANIMAL

The hinged arrangement of the plates of the back permit it to roll up completely.



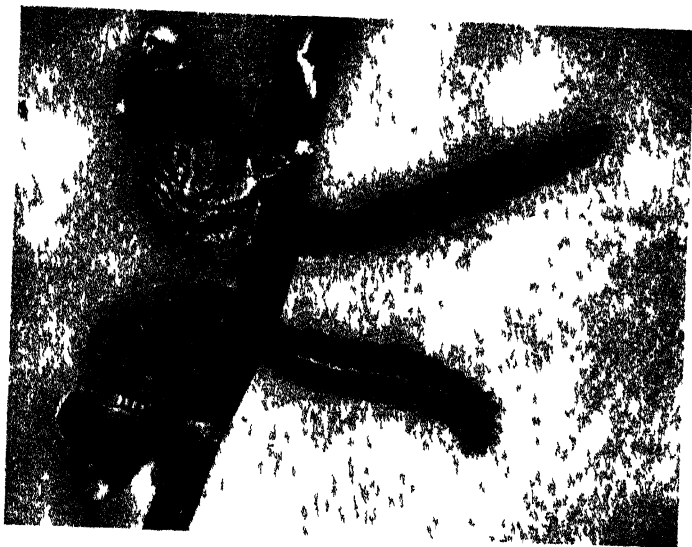
1. FLAMINGOES (PHOENICOPTERUS)

The birds are shown feeding in shallow water, grooming, and resting.



2. WHISTLING SWAN (CYGNUS COLUMBIANUS)

"Tipping up" to obtain food from the bottom. In this position these birds can reach to a depth of about 45 inches.



1 WHITE TUFTED MARMOSET (*CALLITHRIX JACCHUS*)
Two baboons are on the back of the father



2 THE RARE MANED SLOTH (*SCAEOPHUS TORQUATUS*)
A baby is clinging to the mother with its head under her chin its right arm on her shoulder and its right hind leg on her flank Photograph by John Moore



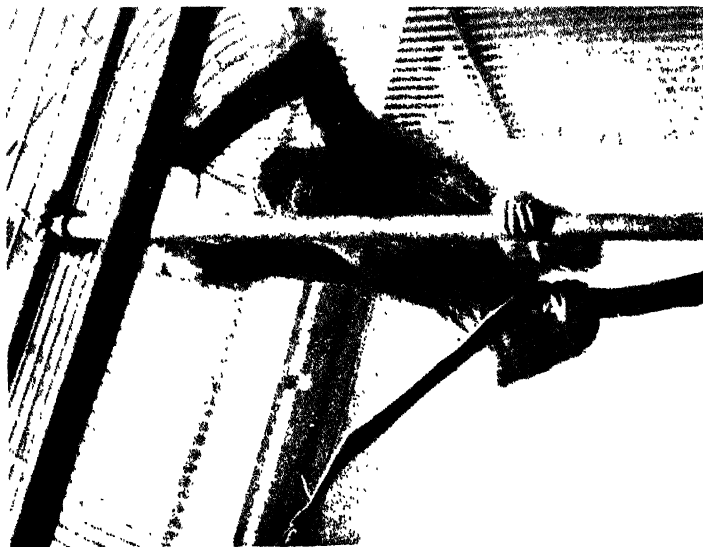
1 FEMALE SOUTH AMERICAN OPOSSUM (*METACHIRUS NUDICAUDATUS*)

This animal lacks the marsupial pouch. Some of her babies clinging to her nipples are to be seen between her hind foot and her tail. (Photograph by João Moojen.)



2. FEMALE SOUTH AMERICAN OPOSSUM (*METACHIRUS NUDICAUDATUS*)

Eight baby opossums are clinging to the nipples between the hind legs of their mother. (Photograph by João Moojen.)



1. SUMATRAN ORANGUTAN (PONGO ABELII)

In its right foot it is carrying a tree limb about 8 feet in length. The remarkable grasping ability of the foot is well shown in this picture.



2. CHAMELEON (MICROSAURA PUMILA)

A highly specialized lizard whose eyes work independently. Its left eye is watching the camera. Note the grasping feet and the prehensile tail. Its tongue could extend far enough to catch an insect on the end of the stick.



SPIDER MONKEYS (*ATELES VELLEROSUS*)

The female in the upper left corner has a baby riding on her back, which has wrapped its tail around the base of her tail. The tip of the mother's tail is holding onto a board.



PLAINS LEAST WEASEL (*MUSTELA RIXOSA CAMPESTRIS*)

Upper and middle, in summer coat; lower, in winter coat (this form apparently does not become entirely white). This is a very rare form of which practically nothing has been recorded, and these may be the only pictures ever taken of it. About three-quarters natural size.



1 KINKAJOU (*POTOS FLAVUS*).
It is steadying itself with its strongly prehensile tail.



2. BIG BROWN BAT (*EPTESICUS FUSCUS*).
The bat is flying over an eastern flying squirrel (*Glaucomys volans*) which is sitting on the author's wrist.



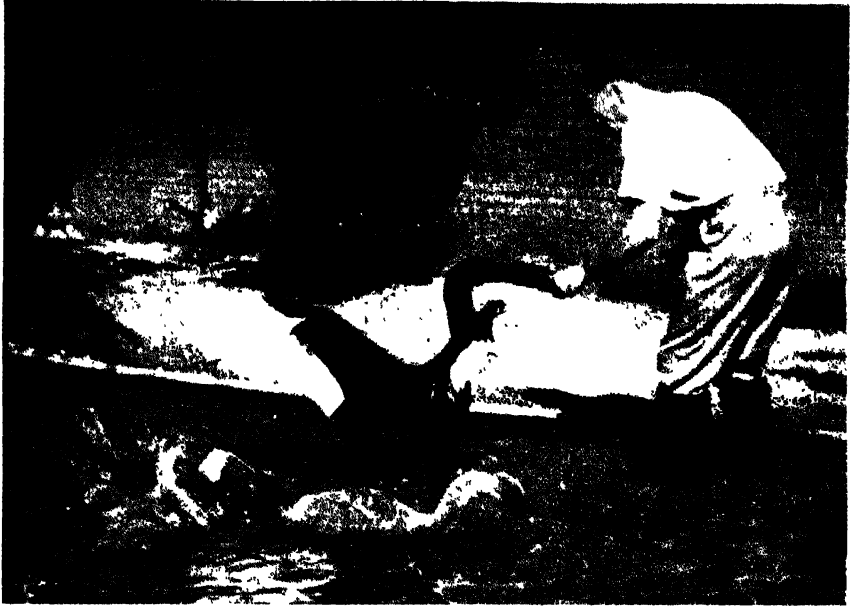
1. TWO-TOED SLOTH (*CHLOEPUS DIDACSYLUS*)

Hanging beneath a limb is its usual pose. The forefeet have two toes, the hind feet, three toes.



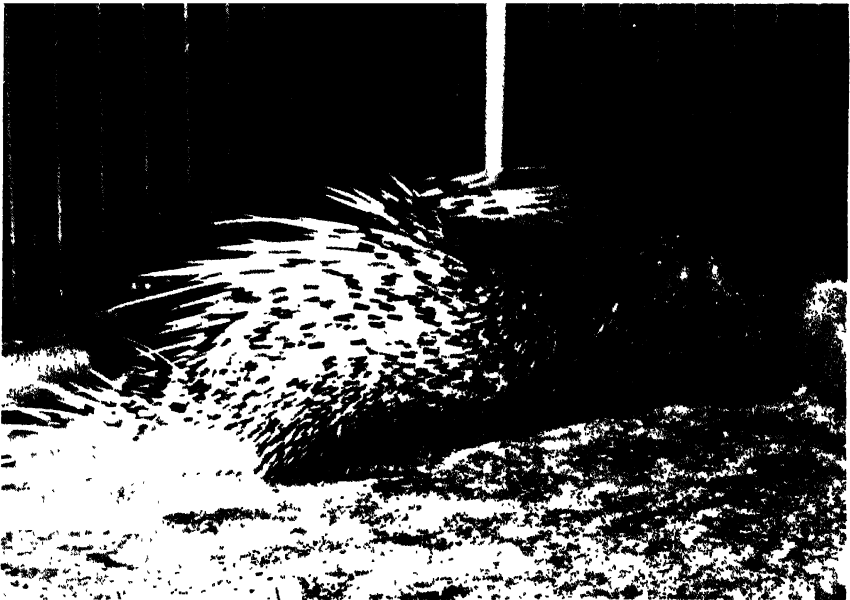
2. YOUNG MALAYAN TAPIR (*ACROCODIA INDICA*)

The striped baby coat is being replaced by the solid gray and black of the adult coat. Age 3 months.



1. MALE BLACK AUSTRALIAN SWAN (*CHENOPSIS ATRATA*)

The bird is attacking a man in defense of the half-grown young in the foreground.
The female was just to the left outside the picture.



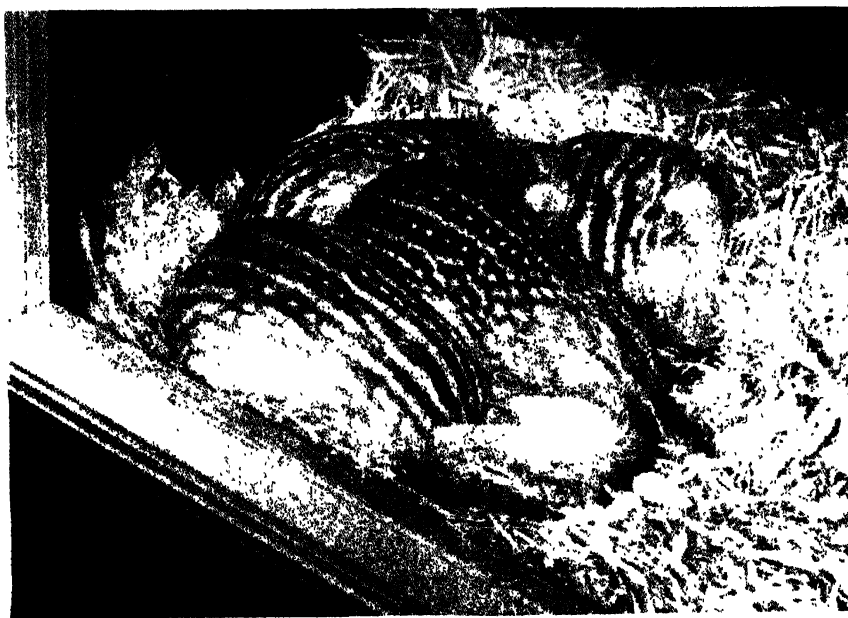
2. MALAYAN PORCUPINES (*ACANTHION BRACHYURUM*)

The two animals alternate head to tail, in which position they regularly sleep.



1 SIX-BANDED ARMADILLO (*DASYPUS SEXCINCTUS*)

The animal is on its side asleep. They tremble almost constantly when sleeping.



2. THIRTEEN-LINED GROUND SQUIRRELS (*CITELLUS TRIDECIMLINEATUS*) ASLEEP

Three rest on the top of their heads, one is lying on its back, and one in the background is mainly right side up.

but we can judge from its structure that it probably eats insects or other soft animal food. The food of carnivores, the flesh eaters, is rather uniformly flesh or fish, but carnivorous animals frequently pass over the principal meaty portions of a carcass to drink the blood and eat parts of the viscera, thereby obtaining valuable vitamins. Almost invariably the glands or other parts which they eat are known to scientific workers as being excellent sources of vitamins. In one experiment that was conducted under my direction, we separated chicken viscera into its various component parts and then offered these to small carnivores. Almost all immediately chose the pancreas, which suggests that it is probably a valuable food. Most people have witnessed a dog burying a bone and later digging it up and chewing on it. It is possible that the bacteria of the soil act on the bone to make it more palatable and more digestible and possibly to eliminate any danger of ptomaine poisoning. A few carnivores, such as the binturong (*Arctictis*) and the palm civets (*Paradoxurus* and related genera), have taken to a diet consisting largely of fruit.

An ingenious method was once demonstrated to me by the West African marsh civet or marsh mongoose (*Atelx paludinosus*) in the National Zoological Park. This animal, about the size of a large cat, had a remarkable method of breaking bones. He was commonly given two pieces of horse ribs 4 inches in length and, when he had eaten most of the meat off of them, he would take a piece of bone between his forepaws, raise himself up on his hind feet with the hind legs well extended and with his forepaws well above the level of his head, and then quickly throw the bone down on the cement floor of the cage from a height of $2\frac{1}{2}$ to 3 feet. If he was not satisfied with the results of the first throw, he would repeat the process. The procedure described suggests that these animals probably use the same methods in breaking the shells of mollusks and land crabs on which they feed in their native haunts of West Africa.

The shortest mammal in the Americas and almost the smallest in the world is the lesser short-tailed shrew (*Cryptotis parva*) which inhabits the eastern United States. It weighs as much as two dimes, less than one-fourth of an ounce, and naturally such a tiny creature cannot cope with large antagonists in the usual manner. It normally lives in loose soil and leafmold where it feeds on earthworms, insects, and a wide variety of small animal life including frogs. Even a vigorous earthworm is a difficult creature for the tiny shrew to subdue in the usual manner, but earthworms lose their activity within a few seconds after the shrew gives them a few light bites; sometimes a single nip will suffice. Apparently the saliva carried into the very minor injury made by the shrew's teeth is poisonous to the earthworms and takes effect very quickly. When the earthworm has become quiet the shrew proceeds to devour it, and it may be that this special-

ized saliva accelerates digestion. Little is known regarding the poisonous bite of these little creatures, but it is apparently similar to that of a slightly larger close relative, the short-tailed shrew (*Blarina*) whose saliva is definitely known to be poisonous to many small creatures and whose bite on a man's finger is sufficiently poisonous to produce pain extending halfway up the arm with resultant irritation lasting as much as a week. Such bites are somewhat comparable to the bites of snakes in which a secretion from specialized glands is introduced under the skin of the victim, although these shrews do not have specialized teeth or glands that are primarily poison producers.

Among the reptiles, the chamaeleon (*Chamaeleonidae*) has the interesting habit of obtaining the insects on which it feeds almost exclusively by suddenly extending its tongue to a distance almost as great as the length of its head and body and catching the unwary insect with it. The tongue is attached near the front of the mouth and folds back into the mouth like that of the frogs and toads, which also capture their prey in a similar manner (pl. 10, fig. 2).

Emil Liers' study of otters (*Lutra*) in North America have shown that these remarkably intelligent and playful animals feed largely on crayfish and numerous small invertebrates instead of fish, which they have generally been supposed to eat. It is strange that this was not discovered long ago, emphasizing the fact that there is still a fertile field for research on animal life.

Through the long period of development of each species, animals have learned that in general each individual or pair requires a certain amount of territory in which to sustain itself. Other species that do not conflict with it will be tolerated in this territory, while those that would be competitors may be driven out. Forms of life that constitute the food supply are rarely devoured to the point of extermination, and animals can therefore ordinarily obtain sufficient food within a rather definite territory. Some require but a small range for this purpose; others must have an extensive territory and move to various parts of it at frequent intervals to obtain the necessary food. For example, the wolf (*Canis nubilus* and related forms), an animal that preys on other animal life, usually has a range about 20 miles in diameter and, except when the female is living at the den caring for the young, it traverses this range, generally in large circuits, returning to any given portion of the range about once every 2 weeks.

Seasonal fluctuation in the food supply, such as the migration of fishes or the dying off of insects, results in the migration of forms that prey upon them to locations in which food can be found. For example, insect-eating birds have an abundant supply of food in the Northern Hemisphere during the summer but, with the approach of winter,

insects and fruits become scarce and many of the birds cannot survive. By migrating to regions farther south, however, they are able to obtain an adequate supply of such food. Some forms that do not migrate change their feeding habits during the year. During the summer when fruit and insects and other animal life are abundant and easily obtained, they feed extensively on these elements, and in the winter they eat seeds and plant life that has matured during the summer. Good examples of this are the birds of the sparrow group (Fringillidae), in which the young are fed almost exclusively on insects and fruit and the parents eat such food extensively when it is available, but during the winter when few insects or fruits are to be had, they feed mainly on seeds. Others feed only on certain types of food and apparently cannot survive unless they can obtain these particular foods. Notable among these are the cross-bills (*Loxia*), birds of the Northern Hemisphere about the size of sparrows with usually some bronze, red, or purple markings. They feed on seeds of the spruce, hemlock, or pine which they obtain directly from the cones by perching on them and reaching under the scales of the cones with their peculiar crossed mandibles and extracting the seeds. Such beaks are probably well adapted for this purpose but are a serious handicap to eating the type of food that most birds consume; therefore these birds are erratic in their occurrence in a given range. If there is a failure of the seed crop of the spruce, hemlock, or pine, they must move to regions in which there is a good crop of seeds on these trees.

Such sturdy, hardy animals as the American bison (*Bison bison*) and caribou (*Rangifer*) have extensive ranges that embrace both summer and winter forage grounds to which the animals migrate seasonally, some making a round trip of several hundred miles each year, measured in straight lines.

We are prone to think of our food selection and handling as being superior to that of animals, but after observing the care with which animals select the choice morsels and pass over food that they detect as being contaminated or not palatable to them, I believe that the wild ones probably are far better fed and are better judges of food than we are. Studies of the feeding habits of antelopes on the native range disclose that in a 14-day period they eat 24 to 30 different kinds of vegetation. Possibly some of the material was eaten as many of us have taken food during war time, merely for the purpose of survival, but obviously they picked and selected foods that they preferred and thought were best for them. If one will watch a wild rabbit or almost any wild animal, he will see that it constantly and carefully selects or rejects food. On many occasions I have endeavored to induce animals, either wild or in captivity, to eat food that I had seen them pass over. Rarely could I get them to do so, and on one occasion,

the third time I offered a certain nut to a very friendly wild squirrel, it took the nut, opened it, and dropped it, perhaps to show me that the nut was not fit to eat.

TRANSPORTATION OF OBJECTS

The need of transporting food, nest materials, or young, and occasionally objects that apparently are taken for ornamental purposes or merely because the animal likes them, have been solved in various ways. Most animals carry objects in their mouths to some extent, just as a dog carries a stick or ball, but there are a number of ways in addition to this: for example, some of the Old World monkeys (*Macaca* and others) have cheek pouches that open inside the lips, but outside the jaws, in which they are able to store food, which must be a great convenience to them when they are trying to obtain their share in the presence of other greedy monkeys. They then grab whatever food they can, put it in their cheek pouches, and eat it at their leisure. Monkeys with food in their pouches sometimes look as though they had mumps on one or both sides. Internal cheek pouches are found in a number of other animals such as the chipmunks (*Tamias* and *Eutamias*) and hamsters, which use them as shopping bags or baskets into which to place food to carry it home to the den where it is stored for future use (pl. 1, fig. 2). Another type of cheek pouch is the external one which is fur-lined. This is present only in a few North American forms such as the pocket gophers (*Geomys*, *Thomomys*, and related genera), the pocket mice (*Perognathus*) and kangaroo rats (*Dipodomys* and *Microdipodops*). Their pockets open outside the mouth, the skin of the face being folded inward to form the pockets. The pockets can be turned inside out to clean them, then pulled back into place by a special muscle. The owners of these pockets carry food, nest material, and even earth in them.

We are so accustomed to seeing mother cats carry their kittens by grasping the skin at the back of the neck that we commonly think of this as being the principal way of carrying young; however, there are many other methods. The mother squirrel grasps the skin of the baby's abdomen in her lips or teeth so that the little one hangs in an inverted position beneath her head, grasping her neck with its hands and feet and curling its tail around her neck, thus aiding in the carrying and leaving no dangling appendages to interfere with mother's hands and feet in her travels through the trees. Baby monkeys cling tightly to the mother in most cases, but the white-tufted marmoset (*Callithrix jacchus*) mothers generally carry the babies only when nursing them; the rest of the time the fathers carry them (pl. 8, fig. 1). They cling to his long fur and ride on his back or under surface and hold on so securely that he can make leaps through the trees without dislodging them. Baby gibbons cling to the mother

on almost any part of her body and frequently take a position around her body almost like a belt.

The Brazilian mammalogist, João Moojen, of the Museu Nacional, Brazil, has informed me that the baby of the rare sloth (*Scueophus torquatus*) clings tightly to the mother and is almost completely hidden in her long loose hair. If no danger threatens, it may cling to her back, which is frequently the underside; however, if danger threatens, it is brought onto her chest or abdomen which is usually her upper side or is between her and a tree trunk. In this position it is well protected between the mother and the trunk or branch to which she is clinging and is so well hidden in the fur that it can scarcely be seen (pl. 8, fig. 2).

We commonly think of the marsupials as always carrying the young in the mother's pouch. This is true for many of the forms, including the common opossums (*Didelphis*) of North and South America, but there are some marsupials that lack the pouch on the abdomen of the mother. In some of these species the young are carried or dragged about by the mother as they cling to her nipples. Good examples of this type are the small South American mouse opossums (*Marmosa* and allied forms) which range in size from about that of a house mouse to that of a common rat. The young hang suspended from the mother's nipples which are in a cluster between her hind legs, and in this location they are well protected. When the young become larger, they are dragged on their backs, as the mother walks along the ground. If one becomes detached from the nipple, it is lost, for apparently they cannot again attach themselves to the nipples, and the mother appears to make no effort to rescue them. The *Metachirus* pictured with the little ones hanging from her nipples had eight babies (pl. 9, fig. 2).

Rodent babies of a number of different forms in various parts of the world also cling to their mother's nipples until they are of good size, and when she travels about on the ground or through the trees, they dangle or are dragged about on their backs. The North American wood rat or pack rat (*Neotoma*) has this habit, and as many as four young, which individually may weigh almost a fourth as much as their mother, will be dragged about by her.

In the Tasmanian "wolf" (*Thylacinus*), a marsupial, the pouch is a fold or shelf of skin on the abdomen between the hind legs which opens backward—a sort of rumble seat—and the young are carried in this. The best pouch of all is possessed by the kangaroos; they carry the babies in a large, deep, baglike fold of the skin of the mother's abdomen until they may weigh almost one-fourth as much as the mother. When there are no young in this pocket, or when they are very little, it is shrunken and drawn up until it is rather small, but as the young grows the pouch stretches and can accommodate one

young until it is well able to take care of itself. There is a muscle around the entrance of this pouch which acts like a draw string and constricts the opening until it is very small, preventing foreign objects from getting in and the young from tumbling out.

The very beautiful, graceful kangaroo rat mothers of North America lift their babies by grasping them by the back of the neck with their lips or teeth. They steady the little ones by holding them with the forearms, then hop along on their hind legs. This method of carrying the young was observed and photographed by that great naturalist, the late Vernon Bailey.

The North American opossum is said to carry leaves and straw for its nest by wrapping the tip of its tail around the material. Some doubt exists, however, that this is an established habit, as only a few instances have been reported.

As previously mentioned, gibbons, orangutangs and chimpanzees frequently carry objects grasped in their hind feet as well as in their hands. On one occasion I saw a chimpanzee pick up a piece of banana in one hand, a piece of bread in the other hand, and a head of lettuce with one foot. The ability to carry objects in the foot is particularly useful to animals that regularly traverse the forest by swinging by their arms from limb to limb. An orangutang carried a limb about $2\frac{1}{2}$ inches in diameter and 8 feet in length from an outside cage to an inside cage in the National Zoological Park, handling it much of the time by grasping it with the hind foot (pl. 10, fig. 1).

A number of the animals that burrow, particularly those that make extensive tunnels such as the pocket gophers of North America, the mole-rats (*Cryptomys* and *Bathyergus*) of Africa, and the bamboo-rats (*Rhizomys* and related genera) of Asia, push the earth before them, placing the hands close to the sides of the head and against the earth and supplying the motive power for moving the body forward by the hind legs. Others scrape earth rearward with the forefeet and then send it farther rearward by strokes of the hind feet. This is the most common method of those that do not make continuous tunnels. The prairie dogs (*Cynomys*) of North America move a great deal of the earth that they use in building mounds by this method, and they also push earth before them.

Beavers carry at least part of the earth or mud they use by holding it against the breast with the hands.

Elephants (*Elephas* and *Loxodonta*) pick up objects by encircling them with the trunk.

Apparently both whales (Cetacea) and seals (Pinnipedia) sometimes hold their young to their sides by means of the flipper. This procedure has been observed so rarely and for such brief glimpses that little is known of it. Whalers say that a mother whale sometimes

uses this method to take her baby under water with her out of danger. Seals may do it for the same reason.

Recently my wife and I witnessed a female black individual of the gray squirrel of the eastern United States collecting bark fiber for her nest. She went onto a dead limb of a tulip tree about 8 feet from our window and began loosening a strip of bark about a foot in length. Some was torn loose entirely but left hanging by a small strand, other parts were not hanging down but were well loosened from the branch. I thought at first she was not satisfied with the quality of the bark, and I was about ready to offer her advice on how to collect bark without wasting so much of it. Finally she began picking up the hanging fibers in her mouth, placing them crosswise and tucking the ends in so they would not drag and be in her way. When she came to the strands that still kept the pieces of bark attached to the limb she cut them off. In a few instances she backed up and pulled them loose by tugging. I then realized that she did not need any advice on how to gather bark with her equipment. She had loosened all the bark she needed but left it attached so it would not fall to the ground, then when she had enough loosened she began gathering it up. Of course she could not have had much loose bark in her mouth and still cut more bark loose from the limb with her teeth. As usual she had done her work in the most efficient way.

Many times I have offered my pet "flying" squirrels a tidbit that they preferred to the one they were eating. This confronted them with a real problem. Their experience through the ages has been not to drop food, for it falls to the ground and is ordinarily lost. They usually solve the problem by looking for a place in which to cache the food they are eating, then come back to me to take what I am offering. Likewise I have many times put the same problem or a similar one up to the gray squirrels (*Sciurus carolinensis*) of the eastern United States. Most of them try to solve it by attempting to take the second morsel without dropping the first. Usually they cannot do this but make several attempts and finally finish by sitting nearby to eat the first piece and then come for the second, or sometimes they give up the attempt and take the first piece home or at some distance to eat, then return for the second. When I am giving them peanuts in the shells there is often an amusing struggle to get two together in the mouth so that they can both be held. Sometimes a squirrel will hug the nuts in its arms next to its neck and take a few short hops to get away and work on them at its leisure. I saw one old lady squirrel develop an ingenious method of solving the problem. After working with the nuts for a few seconds on several occasions she sat there and shelled one of the nuts, put the kernels in her mouth, then picked up the other nut quite easily. Later another learned this method and

both squirrels now do it regularly. Having learned the method, they usually hesitate after I have given them one nut to see if I will give them a second. Why make a trip home with only one nut when they can just as well carry two? The second squirrel to learn this is younger than the first one and may have observed the older one perform the feat, for as pointed out elsewhere I believe animals learn much from observing others of their kind. However I saw the entire process of learning to do the act the first time with both of them, and thereafter it was a regular procedure to use the new accomplishment. Captive love birds (*Agapornis*) sometimes place straws under the upper tail coverts to transport them to the nesting site.

My wife recently witnessed a novel method of transportation adopted by a yellowjacket (*Vespula maculifrons*). The bees were feeding on and carrying away pieces of raisins put on our fourth-floor window ledge for the birds. Generally they cut off a small piece of a raisin and never carried away a whole one, but she saw one bee roll a raisin with its head to the edge of the ledge and push it over. When the raisin started to fall, the bee followed it a short distance, then came back and repeated the process until it had dropped four raisins. My wife does not think the raisin was accidentally pushed over, as the bee's movements seemed aimed at pushing it to the edge. Perhaps the nest was near the building and this bee had discovered an easy way of getting raisins to the nest.

CARING FOR AND TEACHING THE YOUNG

The type and amount of care and teaching that animal parents give the young varies from nothing to a very good education. Any consideration of this subject at once raises the question of how much the animal does by instinct and how much it learns from its parents or others. Of course, no conclusive or complete answer can be given to this, but there are many fragments of information that we can piece together to give us some light on the subject. Some animal mothers never see their young and give them no attention whatever. Among these are such animals as most snakes and lizards, which lay eggs that are hatched by the heat from the soil or from decaying vegetation, and the parent takes no part in their incubation. Exceptions are the pythons (*Pythonidae*) and skinks (*Scincidae*), which incubate their eggs, and the female alligator which stays near the nest to keep away intruders that might harm the eggs. However, the mothers take no part whatever in caring for or instructing the young. The mound-building birds of Australia and New Guinea (*Megapodidae*) do not incubate the eggs or care for the young; the mother lays the eggs in a mass of vegetation which she, together with other birds of the same species, scrape together, and in which all of them lay their eggs as in a sort of communal incubator.

On the other hand many animals, particularly mammals and most birds, give a great deal of care to the young and obviously give them definite instructions. The bears (*Ursus* and *Euarctos*) are well-known examples. When mother bear begins leaving the den in the spring, the young are left inside and are apparently told to remain there. They do not begin coming out for some time—until the mother feels that they have developed enough to need a slightly larger world. She first permits them to play close to the entrance to the den while she stands guard, and later, when they are stronger, she takes them with her on foraging expeditions, at which time she tears open decayed stumps and logs to expose ants, grubs, mice, and other delicacies. Likewise, she turns over stones for animal food that can be found under them, digs up roots, and leads the babies where acorns can be found. Mother bear is a strict disciplinarian and does not permit the young to stray far away. If danger threatens and she feels that for any reason she cannot take the young to the den, she often sends them up a tree while she stays on the ground not far away. She is usually successful in her instructions to them to keep silent, although occasionally a baby will become so frightened that it will cry, which often results in its being soundly spanked and cuffed for its infraction of her rules. If she desires not to send them up a tree but decides to run away, she keeps them close to her, and if they are disposed to lag or become tired, she will sometimes cuff them along ahead of her, sometimes tumbling them end over end so that they will have an incentive to keep up with her. Throughout this entire time, when the young are with the mother, observers have seen that it is definitely a training period in which the mother shows the young where and how to obtain food, what sounds and smells to avoid, and what are apparently safe in their haunts.

Apparently about the same procedure is followed among the foxes (*Vulpes*), wolves and wild dogs (*Canis*), and wildcats (*Felis*), for the mother leaves the little ones in the den until they are able to begin playing about the entrance, where she finally permits them to sun themselves and romp and engage in tussles with brothers and sisters, gaining strength and agility. She brings them food, over which they struggle, and finally she brings live food so that they have the actual experience of handling live prey. Among the foxes and wolves, the father often participates in bringing food, and both mother and father stand guard near the entrance to give the alarm for the young to take refuge inside when danger threatens. Usually a short bark or two is sufficient to warn the little ones to take shelter. When they are old enough and strong enough to venture farther away from the den, the mother takes them on hunting expeditions on which they learn to catch small prey that is within their strength. On these expeditions

they learn to be alert, to beware of danger, to be on the watch for prey and how to catch it, and what to avoid.

Mother deer (*Odocoileus*), antelope (*Antilocapra*), and moose (*Alces*) hide their newly born young and leave them hidden for some days. The baby antelopes may be left in plain sight on a grass-clad or very sparsely vegetated plain. Baby deer are hidden in the grass or sparse shrubbery, and baby moose may be hidden in such places or in slightly more dense vegetation. The mother then goes her way to get her food and rest, and returns to the little one only to nurse it at intervals of several hours. Thus the young are not exposed to the hazards of following the mother for the first few days until they have gained strength and are able to travel with such speed and endurance that they stand a good chance of survival by escaping with her. The mother cottontail rabbit (*Sylvilagus*) scratches out or selects a slight depression in the soil and lines it with fur that she plucks from the underside of her body. The depression is too small for her to be in it with the babies, but she crouches over it, and when the little ones nurse, they reach upward or climb up through the soft downy nest to reach her nipples. The cottontail nurses her little ones only at rather long intervals—apparently not at all during the daytime—and as long as 30 hours are known to elapse between feedings in some instances. When danger threatens she dashes away and the enemy usually follows her.

Mother sea otters (*Enhydra*), which spend a great deal of time in the ocean, lie on their backs much of the time and the babies rest on the mother's ventral surface. When she dives for food she leaves the little one floating on the surface while she goes to the bottom and picks up sea urchins and other food which she brings to the surface and eats while lying on her back.

A mother flying squirrel that raised her family in my home, has given me many glimpses of how she cares for her babies. Flying squirrels are, of course, strictly nocturnal and there would be many hazards for them in the daytime; therefore I was not surprised to find that "Mother Glaucky" carries her babies back into the nest when she finds that they have strayed out during the daytime. Perhaps she and the tree squirrels teach their babies by demonstration and by voice, but I have not been able to detect much evidence of this. The young play among themselves about the nest, gradually gaining strength and agility and venturing farther from the nest. The length of time that baby flying squirrels and baby tree squirrels are weak and uncertain in their movements and are dependent on the mother is much greater than is generally supposed. Baby flying squirrels do not venture out of the nest until they are about 60 days of age and then only to explore in the immediate vicinity of the nest. By the seventieth day they are venturing somewhat farther, but their muscles are still soft and they have not gained agility or confidence.

In the wild they would probably not go farther than a few feet in their own nest tree. It is not until they are about 90 days old that they are ready to assume full activity. Golden hamsters, on the other hand, develop very rapidly, and by the thirty-fifth day, although not full size, they are apparently on their own in all respects.

Swans (*Cygnus*, *Chenopsis*, and *Olor*) are remarkably good parents and keep close watch that their young are protected from enemies. The female generally stays in the background and keeps the young with her while the male goes out to meet the intruder. If the danger is imminent he will approach with a direct rush and make vicious bites with his beak and will strike severe blows with his wings. If the danger is not imminent but he still feels an intruder might do harm he frequently approaches indirectly, that is, comes up to one side of the enemy apparently as though to catch it off guard. On one occasion while I was sitting very quietly on a rock in the swan yard trying to get a picture, the male swan persistently worked around to one side of me and when I did not move he finally grabbed my arm with his beak and tried to strike me with his wings. As soon as I started to move away he was satisfied. In this instance I had been trusting to my lack of motion to allay his suspicions, but my efforts to "freeze" were not successful. One of the poses of the male black Australian swan (*Chenopsis atrata*) threatening an intruder is shown in plate 15, figure 1.

SLEEP

Generally we think of sleep as a very simple state of inactivity which is similar in all animals, but actually the attitudes and types of sleep of various animals differ considerably. I think it likely that most, if not all, of the mammals that live in burrows well beneath the surface of the ground sleep very soundly, as they are comparatively free from danger while in their dens. Naturally, my observations of this fact have been limited and to my knowledge it has not been carefully studied; however, the few creatures of the burrowing type that I have been able to study all seem to sleep very soundly. A golden hamster can be picked up and handled gently within 30 seconds after it has ceased activity and has thrown itself down to go to sleep. I have similarly handled pocket mice when they were asleep in their nests and have found that they were quite difficult to arouse, which is in marked contrast to the great alertness of many other forms.

Animals that live above ground are, of course, subject to a wide variety of hazards when they are asleep and must therefore, as it were, "sleep with one eye open." This is particularly true of rabbits, most birds that sleep in the open and, no doubt, most other creatures that are in similar exposed locations. My pet flying squirrels selected a laundry bag hanging on a bathroom door for their nest and appear

not to be disturbed by the swinging of the bag, which perhaps simulates the swaying of the trees in which they would normally live. They are, however, distinctly disturbed by vibration produced by rubbing the door or the rod on which the bag hangs, which would probably remind them of the disturbance made by an enemy climbing to their nest in a tree. When thus awakened, they usually react in one of two different ways. If sharply startled they are very likely to dash out of the nest ready to take off in a glide or run to another, safer location; or if the alarm is not so sudden they may merely quickly and quietly go to the entrance of the nest and look out to see the cause of the disturbance. This behavior is, of course, associated with the rather exposed location in which they live, where danger may arrive from almost any direction and their best chance for survival may be to flee.

I am inclined to think that the African elephant shrews (*Macroscelides rufescens*) sleep with both eyes open instead of only one. I have kept some in my den to study them at all hours of the day and night, and I have yet to see them with their eyes closed. They are invariably sitting upright with their eyes wide open, or at most only slightly closed. This trait suggests that they probably sit above ground in more or less exposed locations and are perpetually alert for danger.

A wide variety of poses are assumed by animals in sleeping. In addition to the well-known attitudes of lying on the ventral surface, the back, or the side, a great many curl up in a very compact ball. The squirrels and others with bushy tails tuck the head and feet well inside and wrap the tail around them so that it actually affords some protection and warmth for the back of their necks and their backs. In this curled-up position they may lie on the side, but more frequently the head and feet are on the underside with the top of the head actually resting on the surfaces on which they are sleeping. This is a common position among a great many of the rodents. The giant anteater lies on its side, curls its head and feet together, and covers itself with its very long-haired tail which serves as a blanket and, perhaps in the wild, to some extent as camouflage. The sloths sleep hanging beneath a limb with the head thrown upward and forward so that it rests on the chest, or they may be partially sitting in the fork of a tree with the head forward between the upper arms, the tree trunk, and the chest. Some animals sleep standing up. Horses commonly do this, and some elephants do much of their sleeping standing. Most of the bats sleep hanging head downward, being suspended by the nails of their hind feet. The red bat (*Nycteris*), which sleeps hanging on a twig in a tree, has an extensive membrane between the hind legs which it draws downward so that it serves as a protection to the ventral parts of the body. When hanging head downward,

bats are in a good position to take off for flight, for they are generally at an elevated location and have merely to let go with their toes and spread their wings to be in full flight.

I have noticed that the nine-banded, the six-banded, and the hairy armadillos (*Dasypus* and *Euphractus*) all tremble almost continuously in their sleep, particularly when lying on their backs or sides, as they often do. This is unique among mammals with which I am acquainted, but I have no theory to explain it.

Malayan porcupines (*Acanthion brachyurum*) like to sleep side by side and have an interesting method of avoiding the spines of another that has already lain down. Each succeeding one merely faces in the opposite direction from the last one in the row. I have seen as many as five lying asleep in such alternating head and tail positions, but when I tried to take their pictures in this arrangement I usually disturbed some of them, so that I have never been able to photograph more than two together (pl. 15, fig. 2).

The tiny bat parakeets (*Loriculus*) sleep hanging head downward, clinging to the perch by their feet.

Of all the small mammals I have observed the females are much more particular regarding the nest than the males. The females will move it about, cut on the nest box, assemble nest material and keep it well shaped into a snug nest, whereas most of the males are far less particular, usually working on the nest only enough for it to be passably comfortable. Of course, my wife noticed this before I did and pointed out that females have stronger instincts for home maintenance than males.

Most mammals, when they have the opportunity to awaken naturally, like to sit and "think," or perhaps just sit, like many people who cannot start off "in high gear." Those that I have observed, after about half an hour start normal activity.

Hibernation was discussed briefly in my previous paper on Animal Behavior and has been extensively treated in other literature so will not be further mentioned herein.

CONCLUSION

The better our knowledge of animal habits and behavior, the better we are prepared to cope with the problems in connection with animal life and the administration of resources in which animals play a part of greater or less importance. Biologists are constantly being confronted with problems of how to control, circumvent, keep away, or increase wild life. The problems may be simple or very complex, but are always interesting.

Wildlife administration has become an important branch of national, State, and local government work for we have come to realize that many of the forms are highly beneficial and should be protected and

built up to the maximum possible numbers, and that a few are injurious and should be controlled.

As the activities of mankind are extended, the importance of wildlife protection increases correspondingly, for we could not live without animal life and the extirmination of any form is a serious loss. Better understanding of animals leads to recognition of their value and therefore to more interest in their protection, and the study of animal life as a profession, as a hobby, or merely through casual observation yields much pleasure.

NOTE.—All photographs are by Ernest P. Walker unless otherwise listed.

THE BREEDING HABITS OF THE WEAVERBIRDS

A STUDY IN THE BIOLOGY OF BEHAVIOR PATTERNS

By HERBERT FRIEDMANN
Curator, Division of Birds,
U. S. National Museum

[With 8 plates]

The weaverbirds, as their popular name implies, are, by and large birds noted for the elaborate nests they build—in many cases actually weave—out of grasses, straws, rootlets, and other similar materials. Included in this family (Ploceidae) are some of the finest, most expert, and most famous of all avian architects. In no other single bird group of similar status has the habit of nest building been carried to greater heights, indeed their only rivals for excellence in this particular are some of the hang-nests or troupials of the New World.

My interest in the weaverbirds began some 30 years ago when I had the opportunity of studying the actual weaving methods in captivity of one species, the red-billed weaver, *Quelea quelea*. Not long afterward when I began my studies of parasitic birds I learned that at least two species of weavers, and possibly several others, not only built no nests at all, but laid their eggs in the occupied nests of other kinds of birds to whose care the eggs and the subsequent young were left. A few years later, over a year's field work in South and East Africa gave me ample opportunity to become familiar with the surprising range of aspects the nest-building habit exhibits in this family of birds. In this paper it is not my purpose to attempt to describe each and every one of these aspects, but to discuss them from the point of view of the biological implications they present. The family is a large and varied one and contains a great many species (about 275), many of which have highly divergent nesting habits, which offer very suggestive data to the naturalist concerned with the evolution of habits in birds.

In order to appreciate more adequately the significance of the various aspects of the nest-building habit in these birds, and to evaluate them more properly in connection with other parts of the life histories of birds involved, it is necessary to make a few preliminary

general remarks. Birds, as a rule (there are, of course, exceptions), go through a fairly definite cycle of behavior patterns during the year, and repeat this cycle every year of their adult lives. Very briefly stated, the cycle consists, in typical fashion, of the following parts: Migration or, in the case of nonmigratory birds such as the weavers, the fragmentation, or breaking-up, of "winter," nonbreeding flocks into pairs of birds; the establishment of individual breeding territories (the extent and definiteness of which vary in different species); courtship and mating; nest building; egg laying; incubation; care of the young; and, finally, migration or the return of the individual birds or pairs to the "winter" flocks. Each of these parts of the whole cycle is subject to great variation, and each may be influenced in its development and expression by its antecedent stages, and each may exert a similar influence on its succeeding stages.

Like any other sequence of events or stages, the undue development of any one part may tend to throw out of line one or more of the remaining parts. When everything runs smoothly according to what may be looked upon as a normal pattern, it is very difficult to observe the sequential effects of each part on its successor and it is rarely possible to get even vague glimpses or hints of how the perfected whole cycle came to be developed through the ages. It is only when something deviates from this normal pattern that we have much chance of learning anything of the factors that control or influence it. With these general thoughts in mind, it is instructive to examine in some detail what has transpired in one family of birds with respect to one part of the life cycle, the nest-building habit, and, in connection with it, to related portions of the cycle.

The weaverbirds have been divided into a number of subfamilies (the exact number differing in different classifications), which in a general way are characterized by different nest-building habits. The arboreal, so-called typical weavers (*Ploceinae*) construct a suspended type of woven nest, usually shaped like a ball or a closed oval with a lateral or a downward-extending entrance tube or "vestibule." Most of the species of this group are colonial, sometimes as many as 50 or more nests being built in the same tree, and often with no others on any of the surrounding trees for considerable distances. On the other hand, some species are quite solitary, like Reichenow's weaver (*Ploceus reichenowi*), of which usually only one, and apparently never more than two pairs nest on the same tree, and in those cases where there are two, only one seems to be breeding at a time. The instinct to build is, however, very strong in most members of this group as far as known. Thus, Bates (1930, p. 484) noted of the hooded weaver (*Ploceus cucullatus*) in Cameroon that ". . . it seems to be a necessity of the birds' nature to be always busy with their nest; they will occupy themselves in their spare time with tearing down

unused nests, strewing the debris on the ground under the tree . . .” Of the spectacled weaver of South Africa (*Ploceus ocularius*) Roberts (1940, pp. 337-338) records that the nest has a protruding entrance tube which is usually from 3 to 6 inches in length, but that in several instances the nest-building activities of the birds were so great that the entrance tubes became extended to a length of 6 feet! One nest in the Albany Museum at Grahamstown, recorded by Stark, has an entrance “upwards of 8 feet long.” It is a well-known occurrence in captivity, such as in zoological parks, for different species of weavers, when given quantities of raffia or straw, to weave a vast quantity of rather formless masses of compact, densely woven material over the branches in the cage and even over the wire mesh of the cage itself. The birds do so equally avidly whether they are in breeding or in nonbreeding plumage; in other words, the urge to build, which in most birds is seasonal and is part of the cyclical sequence of behavior patterns, is here extended far beyond its normal limits. Furthermore, in at least some of the species of typical weavers (many are still very poorly known as far as details of habits are concerned), the bulk, if not all, of the actual nest construction is done by the males and not by the females. (In most ordinary birds the female does most of the nest building.) Thus, in the masked weaver (*Ploceus velatus mariquensis*) Taylor (1946, pp. 145-155) found that the males did all the nest building, except for some of the lining which was put in by the females. When a nest is completed the male that built it immediately starts to make another, and in one colony a single male wove no fewer than 11 completed nests.

In another species, the Baya weaver of India (*Ploceus philippinus*), Ali (1931) found that the males were polygamous and that the number of mates each was able to get depended on the number of completed nests he was able to build for them, the actual courtship and mating behavior taking place in or around the newly finished nest. Ali writes that in his experience with this species—

. . . in the initial stages of an adult nesting colony, no hens are as a rule in evidence, and I have been unable to discover their whereabouts during the first few days. It would appear that the instinct to breed asserts itself earlier in the adult cocks than in the hens, for it is not until the time when the nests have progressed to a stage where the egg-chamber is finished or nearly so, that some of the females first become physiologically “ripe.” They now visit the colony quite obviously with the sole object of “prospecting” for laying sites, i. e., to discover if there are any nests that are ready for their occupation. . . . Two hens often fight for the possession of an acceptable nest. The successful hen henceforward boldly enters the nest and busies herself with finishing off and making the interior comfortable. In no case have I been able to observe the cooperation between male and female so often described. The lion’s share of the building—in fact *all* of it—is undoubtedly done by the cock alone. Her contribution is only the “interior decoration”. . . The “building mania,” as it has been called, that comes over the adult cock at this season is a sure indication of his readiness to breed . . .

While my own field notes are less detailed for any one species of weaver than are Ali's on the Baya, I found males of a dozen or more related African species actively engaged in nest building. In the cases where my notes are fullest (the Cape weaver, *Ploceus capensis olivaceus*, the black-headed weaver, *Ploceus nigriceps nigriceps*, and the Kenya vitelline weaver, *Ploceus vitellinus uluensis*) my observations indicate that the male does most of the nest weaving, if not all of it. In some other species (Jackson's weaver, *Ploceus jacksoni*, and the spotted-backed weaver, *Ploceus spilonotus*) there seemed to be more activity among the females in this regard but still the bulk of the building was carried on by the males. (It may be that some of the "females" were really males in nonbreeding plumage, a point that could have been determined only by more collecting at the time. That this is not unlikely may be adduced from the fact that in my field notes on the masked weaver, *Ploceus velatus arundinarius*, I wrote that the females take part in the nest-building activities, but Taylor's careful study of a slightly different subspecies of this bird, referred to above, convinced him that the males did all the actual construction and that the females merely added or rearranged some lining materials. It may well be that the birds I recorded as females were males that had not yet come into nuptial plumage.) Chestnut weavers (*Ploceus rubiginosus*), watched in captivity, showed more nest-building activity among males than females. Of Speke's weaver (*Ploceus spekei*) van Someren (1916, p. 409) noted that, "dozens of nests are built by the male, but only one is occupied; thus there are always plenty of old nests in all stages of completion."

In one of the forest-dwelling, relatively solitary, or at least not highly colonial, typical weavers, *Malimbus cassini*, of West Africa, Bates (p. 478) found that both sexes take care of the young. He shot a male and a female at their nest, which had, "... a woven entrance tube 2 or 3 feet long, so thin that its walls were transparent, and the birds could be seen entering and leaving, feeding young." In the Cape weaver, *Ploceus olivaceus capensis*, previously mentioned, Skead found that both parents fed the young, and it appears that this behavior is fairly widespread in the entire group.

Another section of this subfamily contains the so-called bishop birds (*Euplectes*) and the whydahs (*Coliuspasser* and its close allies). These birds are far more terrestrial than the members of the genus *Ploceus* and their habits are somewhat different. Lack (1935, pp. 817 ff.) studied the fire-crowned bishop (*Euplectes hordacea hordacea*) in Tanganyika Territory and found that the males are polygamous and do most of the nest building, each female merely finishing or lining the one it occupies, and each hen continuing to add to the nest throughout the period of incubation, eventually making it so thick that the observer can no longer see through it, and adding a small saclike ledge

above the entrance. One male was found to have three mates at the same time, and may have had still others. The males have very definite territories and the hens apparently seek out the established cock birds. Actual mating takes place when the nest is in process of being built by the male, but the female has, in all probability, already settled in his territory for some time before this. Incubation of the eggs and feeding of the young are solely the business of the hens, which incubate chiefly at night, the warmth from the sun presumably being sufficient for the eggs during the daylight hours.

Less complete data on the whydahs (*Coliuspasser ardens* and *C. jacksoni*) suggest that these birds are monogamous. Thus, in writing of the latter species Jackson (1938, pp. 1469-1470) states that he regards the evidence against the supposed polygamy of this whydah as conclusive. Near Nairobi, Kenya Colony, he had extremely favorable conditions for watching this species within a fenced-in enclosure with open grass, outside of which enclosure the grass had been burned.

In such a small area it was easy enough to count and mark with a stick each dancing ground. This done, the whole area was hurriedly quartered with the aid of two boys to move and frighten away all the birds present; we then retired a short distance, sat down and waited for them to return. The cocks very soon appeared; the females were much more wary, but returned in due course. Some of them settled in the grass and remained there, evidently on their nests, while others were occupied in going to and fro with fine grass in their bills; these latter rarely remained hidden for more than a minute at a time. Next day we returned, and by quartering every yard of the area we discovered four nests with three eggs, three with two eggs, one with a single egg and three not yet completed. Each nest when found was marked by tying a knot in a wisp of tall grass close by. At the end of a week we again returned; but no more nests were found, and on no occasion did the females equal the number of cocks, but I accounted for this through my failing to detect one or two of them as they sneaked back to their nests containing incubated eggs . . .

At least it seems from this account that there were not more hens than cocks as would have to be the case in a polygamous species.

Unlike many of the weavers whose courtship is performed at the newly constructed nest, a group of males of Jackson's whydah makes a roughly circular dancing area by breaking or snipping off the tall grass to make a clearing of from 2 to 6 feet in diameter. In the middle of this clearing are left standing a sizable number of grasses forming a dense tuft into which the males partly excavate little recesses. Then a number of males go through a leaping performance, generally with no hens around to watch them. Jackson describes the position assumed by the cock as follows:

The head is thrown back like that of a proud Turkey-cock, the beak being held horizontally; the feet hang downward, the tail is held straight up till it touches the ruff at the base of the head and neck, the ends of the feathers falling in a curve downward, with the exception of two tail-feathers which are held straight out and downward.

While actually rising in the air the half-open wings are worked with a very quick shivering motion, and the feet are also moved up and down very rapidly, beating the air.

The bird springs straight up in the air, sometimes for a few inches and sometimes to the height of two or more feet, and then drops.

The whole of the plumage is much puffed out throughout the performance, which is repeated five or six times, with a short interval for rest.

The game would appear to be somewhat fatiguing, as the bird rarely makes more than five or six jumps at a time without a short rest . . . They very often assume their curious jumping attitude some little distance before they arrive at their playground . . .

Besides the data quoted above it may be added that apparently but one male may make use of one dancing area, and that often at the end of the jumping dance it appears to try to burrow into the shallow recesses of the central tuft of grasses (as though there were nests there).

Jackson's whydah shows the courtship behavior pattern developed to a greater degree of display and ostensible rivalry between males, and to a greater specialized areal usage (courtship, or dancing, ground as contrasted with nesting site or even breeding territory) than others of its relatives, but the difference seems to be more one of degree than of kind. As typified by its habits, this section of the terrestrial Ploceinae may be said to be characterized by elaboration of courtship behavior from individual displays near the nest to a complex display at a dancing ground, and by what seems to be monogamy. (More detailed information is needed on this point, however. In the case of the black whydah, *Coliuspasser concolor*, and of the red-collared whydah, *Coliuspasser ardens*, there are observational data supporting a monogamous state; in the long-tailed whydah, *Coliuspasser procne*, similar but less extensive data suggest polygamy.) Recently V. D. van Someren (1945, pp. 131-141) has concluded that Jackson's whydah is polygamous, but his own presentation of the case is not too positive. Thus, he writes that—

. . . polygamy appears to be general, and seems to arise because of the imperfect correlation between the maturation of the males and females. Some males mature early, others late, and the early males may cease dancing and start moulting while later males are just beginning to assume breeding plumage and dance. This irregular maturation of the males may be spread over several months, while by contrast, the females mature almost simultaneously, and all nests are found at the same stage of building or incubation within a few days. Since the sex-ratio of the mixed flock is almost 50:50, late maturing males are thus able to mate with several females, because the mature females probably now outnumber the mature males. Males may commence dancing some four months before the first nest is found, but these early males are probably unsuccessful at mating because of the unready state of the females. Males may start dancing while still in non-breeding plumage, but the behaviour pattern of these immature males is undeveloped in several respects.

It may be noted that the assumption that late-maturing males are able to have several mates is based on the thought that more females are mature in the later than in the earlier part of the season, but, only a few lines above, van Someren informs us that all the females mature simultaneously, which would imply that the females mature later than the early-maturing males. It would seem, from this, if van Someren's assumption be correct, that the early-maturing males might be no longer in breeding condition late in the season when mates are available, or else they would compete with the later-maturing cocks for the hens to a degree sufficient to diminish the likelihood of the late-maturing mates having more than a single mate apiece.

The care of the eggs and the young appears to be left wholly to the females, and, as far as the incomplete evidence goes, the actual nest building is also done by the hens of the various species of whydahs.

We have but little reliable data as to the territorial aspects of the lives of most of these birds, except for Jackson's whydah. In his study of this bird van Someren found that—

. . . true territorial behavior becomes evident early in the sexual break-up of the flock. The males, isolating themselves on rings (*i. e.*, dancing areas) establish a well-defined territory of small extent, of which the ring itself is the focal point; the territory extends all round the ring at a radius of 6 to 10 feet from the central tuft.

A female alighting anywhere within this territory may be solicited by courtship behavior by the male on the ring, even though she may not alight on the ring itself. Another full-plumaged male alighting on this territory is treated in one of two ways, depending on the attitude of his tail as he alights. If he alights with his tail arched and the two outer plumes drooping as in the dancing attitude, he is attacked with pursuit flight if the owner is present in the territory. If however, the intruding male alights with his tail folded in the normal flight attitude he is usually solicited and displayed to be the owner as if he was a female. It is very noticeable that when a male returns to his territory from outside it, the tail is arched and the two outer plumes drooped the moment he crosses the boundary; the bird alights in the dancing attitude, and thus shows his ownership by his appearance . . .

Where two or more rings are found within a few inches of one another . . . they are all formed by the one male, who may use them alternately while dancing, and keep them all in good order . . . rings occupied by two separate males are not found closer than about 12 feet. These boundaries are accepted by the other members of the flock early in the break-up, hence territorial squabbles are seldom seen late in the season . . . This territory is related purely to sexual functions and has no food significance; feeding is carried out in a mixed flock even in the height of the dancing season, on neutral ground where sexual rivalry is notably absent.

Furthermore, this territory appears of no significance to the females apart from the fact that they are attracted to the rings; they are unaware of the boundaries of the male territories. At nesting time, the males cease dancing vigorously and the main dancing area may become completely deserted; the females nest in a different area which is usually some distance away from the dancing grounds. The

nests tend to be grouped together, and are usually about 20 to 30 feet away from the nearest ring if males have been dancing previously in the neighborhood, i.e. well outside the territory boundaries.

In connection with the development of courtship posturings, it may be pointed out that, unlike the members of the arboreal *Ploceinae*, the whydahs, and, to a somewhat lesser extent, the bishop weavers, have very marked sexual dimorphism in the breeding plumage of the adults and many species have elongated or otherwise specialized plumes in the nuptial dress of the males. In the nonbreeding season the sexes generally look alike.

Before going on to the next subfamily, we may briefly summarize the situation in the typical weavers (*Ploceinae*). Many of the species are colonial (which means, in effect, that in most of them the individual nesting territories are nonexistent), and in those species that have been most fully observed the nests are built largely or wholly by the males. Furthermore, in some forms it seems that the males are regularly polygamous and that the number of mates each one acquires depends on the number of nests he has been able to provide for his mates. From the standpoint of our hypothetical "standard" picture of the cycle of breeding behavior patterns this implies that the first stage—migration or the fragmentation of flocks into individuals or pairs—is omitted, that territoriality is likewise skipped, and that the usual sequence of courtship and nest building is reversed. As we have noted, the actual courtship and mating takes place in and about the newly completed nests the males have constructed. The *Ploceinae* take 2 years to acquire adult plumage and to come into breeding condition.

This summary is correct as far as it goes, but there is still one more variation in the reproductive behavior pattern exhibited in this subfamily. One species, sometimes called Rendall's seed-eater, sometimes (and more properly) the cuckoo finch, *Anomalospiza imberbis*, a bird with no very close relatives, but apparently nearer to the bishop weavers than to any other assemblage, is wholly devoid of any nest-building or incubating or rearing instincts, and is, in short, parasitic. It is still very imperfectly known, and all that may be said with any certainty is that it is parasitic on small ground-nesting (or near the ground nesting) warblers of the genera *Cisticola* and *Prinia*. (Six species of the former and one, possibly two, of the latter genus are known as hosts of the cuckoo finch.) As Delacour (1943, p. 71) has recently pointed out, the fact that *Anomalospiza* agrees with the *Viduinæ* in being parasitic does not necessarily imply close relationship to the members of the latter group. In most respects it seems best placed, taxonomically, with the *Ploceinae*, but, it must be admitted, is an aberrant member of that group. It is a slightly gregarious bird, living, at least in the nonbreeding season, in loose flocks. Nothing is on record concerning its courtship, sexual relations, or territorial habits.

The next subfamily is a much smaller assemblage—the buffalo weavers (*Bubalornithinae*)—containing only two species, each with several races. Unlike the typical weavers these birds do not construct nests of fine weaving and elaborate structure, but make rather bulky, massive nests of twigs and thorny branches, rough and untidy in general appearance, and not suspended from, but placed on top of, the branches of large trees (in my experience often baobabs). The birds are colonial and the nests are often placed so close together that they are actually in direct contact with one another. Jackson (p. 1380) records that he saw where branches had given way under the combined weight of too many of these nests on several occasions. Brehm found as many as 18 nests in 1 mimosa tree in northeastern Africa. The nests are often 2 or 3 feet across and are used and repaired and added to year after year. Each nest of the black buffalo weaver (*Bubalornis albirostris*) contains two or more chambers, lined with grass and straw, each with an entrance facing away from the other. The only nests I ever saw of the other species, the white-headed buffalo weaver (*Dinemellia dinemelli*), had but a single chamber. There are descriptions in the literature of nests of *Bubalornis* containing more than two entrances. Priest (vol. 4, p. 220) writes of one that “. . . there were numerous entrance holes, and it looked as if about a dozen birds lived in each of these communal nests . . .” That the urge to build is extended in these weavers beyond the usual small part of the annual cycle of most birds, as it is in the Ploceinae, is indicated by some observations made in Darfur, in the Sudan, by Lynes, who noted that “. . . at all seasons we found these Textors (= *Bubalornis*) hanging about their everlasting great nest-clusters, into which, even in midwinter, birds with quite inactive sexual organs would sometimes carry twigs as if nesting . . .”

Many years ago, in southwestern Africa, Andersson described the nests as follows:

The collective nests consist externally of an immense mass of dry twigs and sticks, in which are to be found from four to six separate nests or holes of an oval form, composed of grass only, but united to each other by intricate masses of sticks, defying the ingress of any intruder except a small snake. In each of these separate holes are laid three or four eggs . . . I obtained no less than forty of these eggs . . . and on the following day the birds were busy in repairing one of the collective nests which had been injured during the collection of the eggs . . . I believe these nests are annually added to, for, so far as I have been able to see, the same nest is retained for several consecutive seasons.

We do not have nearly as complete information on the buffalo weavers as on the typical ones, but what data are available indicate that the birds are colonial, that there is little or no observable evidence of any prenuptial fragmentation of wintering flocks, and that the males do at least part of the nest building. Whether they do it all or not is still unknown.

The evidence does suggest that the nest-building habit is indulged in out of the breeding season and by nonbreeding birds; not too different from the typical weavers in this respect.

The next subfamily, the sparrow weavers and 'social weavers' (Plocepasserinae), shows a great indulgence in nest building, in and out of the breeding time, which culminates in the truly gigantic communal structures of the social weaver (*Philetairus socius*). Thus, of one South African sparrow weaver, *Plocepasser mahali*, Roberts (1940, p. 332) writes that—

. . . a single pair of birds will construct as many as a dozen nests of whitish grass stems on the projecting branches, these being arched over the top with two entrances below on opposite sides, so that there is no cavity for the eggs and evidently made for amusement only; the nests in which the eggs are laid have only one entrance and are warmly lined with feathery grass tops . . .

A somewhat different description is given by Stark (1900, pp. 84-85) who informs us that the species is—

. . . of social habits, it remains in flock all the year round and breeds in company, several nests being generally built in a single tree. Rarely have I met with more pugnacious birds; the males in spring are constantly fighting, and so desperate are their quarrels that the combatants frequently lie exhausted, side by side, on the ground, incapable for further movement . . . The nests are large, roughly built, kidney-shaped structures, usually placed near the ends of the branches of a mimosa or other thorny tree. They are constructed of long grass-stems, the blades and flowering tops being woven together, the stiff stalks projecting in all directions. During the winter each nest has two entrances from below, separated in the interior by a narrow bridge of grass, on which the birds roost. At the beginning of the breeding season one entrance is stopped up with leaves and grass, a shallow cavity being left in which the female deposits two or three eggs . . . As soon as the young are on the wing, the second entrance is unstopped, and the nest is again used, both by the old and young birds, as a roosting place. The nests are annually repaired and last for many years.

A somewhat similar account holds for another species, the gray-headed social weaver of East Africa, *Pseudonigrita arnaudi*. Jackson (p. 1384) comments on the remarkable nest of this bird—

. . . it is very large and quite exceptionally compact, and has two entrances pointing downwards. During the period between breeding seasons these nests are used for roosting, the birds resting on the ridge between the two entrances. In the breeding season one of the holes is stopped up and the eggs are deposited in a depression beyond the ridge on the material used for stopping up the second entrance. The nest is firmly woven to several twigs or branches . . . in small clumps of five to eight nests together.

Of a slightly different race of the same species Jackson found (p. 1385) the nests ". . . were packed together so closely as to form almost one compound nest."

Probably the most remarkable of all weaverbirds' nests is that of the famous sociable weaver of the western arid portions of South Africa, *Philetairus socius*. The enormous communal nests built by

these little sparrowlike birds attain truly great proportions—as much as 25 feet long and 15 feet wide at the base and from 5 to 10 feet in height! While each nest is the product of not a lone individual, or even a pair, but of a whole flock of as many as 75 or 80 pairs, still the sheer bulk of the nesting material gathered and placed by the birds is a striking testimony to the tremendous year-round urge of the nest-building instinct in this species. The time I spent studying this bird in the western Transvaal in 1925 was one of the most fascinating experiences an ornithologist could have, and I cannot refrain from including here part of my notes, at the expense of repeating some items already published in an earlier paper (1930).

As the common name of the bird implies, *Philetairus* is very social in its habits; in fact it is probably as social as any bird could possibly be. It is always found in flocks, feeds in flocks, and breeds in large, many-apartmented compound nests. The smallest flocks that I saw contained about 20 birds; the largest one at least 150. The flocks seem to stay pretty much in the same general vicinity all the year round, and the birds use their huge, massive nests as roosting places during the nonbreeding season. With this extreme sociability and sedentary habit of life the territorial relations of the species have been modified in a way that is quite remarkable, perhaps unique among birds. Instead of each pair of birds having its own breeding territory, each flock seems to have a definite territory, and as the individual flocks are usually far enough apart not to compete with each other, the boundaries of these territories are seldom crossed by individuals of other flocks and other territories. However, in a few cases in my own experience two flocks were fairly close together (i. e., two nests were on trees not very far apart), and the birds mingled more or less while feeding, but in these cases far more fighting and quarreling was observed than in all the others together. In an area approximately 100 miles long and 10 miles wide, or 1,000 square miles in all, I found only 26 nests of the social weaver, so it can be seen that the flocks ordinarily do not live in very close juxtaposition to each other. (The nests are so large, and so conspicuous at great distances, and the country so open and easy to examine, the trees being so relatively few in number, that I am quite certain I found practically every nest in this area.)

The nests observed varied in size as did the flocks. The smallest nest found measured about 3 feet in diameter at the base and was about 3 feet high and had about 10 entrances on the under surface, indicating that it contained that number of individual nests. The largest one found was incomplete, i. e., a piece of it had broken off, breaking its supporting branches by its weight, but the remaining part was a large, flat, horizontal mass of straw, more or less repaired at its broken edge, and measured about 25 by 15 feet at the base and

was about 5 feet high. The part that had broken off must have been about 5 feet in diameter each way. This nest contained about 95 nests within it.

In a locality where these birds occur it is impossible to remain long unaware of their presence. Trees are not so numerous but that each one becomes an object of more or less importance in the landscape. Needless to say a tree on which there is a social weaver's nest is a very conspicuous object, visible for a great distance and widely proclaims the presence of the builders. But the birds themselves soon intrude upon one's consciousness with their noisy, harsh, chattering notes as they fly by in flocks or feed in scattered bunches upon the seeds of the small, stunted shrubs and plants that wrest an existence from the inhospitable soil. While feeding they keep up an incessant chatter much like a flock of house sparrows, and, like them, frequently quarrel over bits of food. In flight they all act in unison with a precision quite remarkable for birds of their type, the whole flock turning, rising, falling, wheeling, and stopping more or less together.

Although the birds live in compound "apartment-house" nests, feed and fly in flocks, and are at all times exceedingly gregarious, they seem to establish fairly strong mating relations as far as my field observations indicate. If they were haphazardly promiscuous they would be forever in each other's way getting in and out of the entrance holes of the individual nests in the large communal structures. As a matter of fact, the harmony of life within each colony, the lack of what may be likened to traffic congestion, i. e., the coming and going of birds in the task of providing food for the young, the fact that out of numbers of individual nests examined by various observers none were found with unusual numbers of eggs or young, all argue for individuality in nest occupancy. Whether each male has only one or several mates is, however, unknown.

There have been several attempts to explain the structure of the large, composite nests of this species, some writers claiming that each pair of birds builds an individual nest, all of them close together, and then the flock builds the common roof over all the nests, while other writers have recorded that the flock builds a large structure and then each pair builds its individual nest into this structure. I never saw the actual beginning of a nest, and the smallest nests I found were, as mentioned above, complete structures with numbers of nests within them. However, Roberts (1940, p. 333) describes the construction of the communal nest as follows:

. . . first a roof is constructed of coarse straws in the strong branches of a large . . . tree, and under this a great number of nest-chambers are made by nipping off the straws to form a tunnel upwards with a chamber at one side of the top of the tunnel; each pair of birds has its own nest-chamber, and scores of pairs may occupy the same colony.

To this I may add that regardless of how the first start is made, it is true that all through the nonbreeding season, the entire flock does a large amount of roofing and general enlarging of the whole affair so that it is true that subsequent individual nests are built into the large structure. The nests are added to year after year, and frequently become so large and heavy that they break the branches upon which they rest, and crash to the ground. All the birds seem to work together equally, apparently the males as well as the female(?)s, and even during the breeding season, when they have eggs or young in the nest, the male birds may be seen carrying straw to the roof or other parts of the common structure, not necessarily close to their own respective individual nests. The huge, massive affairs are composed wholly of dried grasses of a rather coarse, tough sort that grows commonly in southwestern Africa, and the seeds of which enter into the diet of the weavers very largely. The material is not really woven or even plaited on the surface of the nest, but is rather roughly put together in about the same way that hay is put into a well-made hay rack, but with a fairly definite thatching arrangement, causing the rain to run off and not soak through. The under side of the nest presents the rough, hard ends of the coarse straws and forms a very uneven surface.

In the sparrow weavers and social weavers (subfamily Plocepasserinae) we find, then, as far as our incomplete data permit us to generalize, an annual behavior cycle characterized by lack of migration or winter flock fragmentation, a substitution of a communal flock territory for individual ones as far as nesting is concerned, and a very marked development, both in seasonal duration and in individual activity, of the nest-building habit. The published observational data indicate that both sexes participate in nest building, but these data are open to question because of the similarity in plumage of the males and females; whether one or the other does most of the construction is not known. Nothing appears to be on record concerning the courtship habits, so it is not possible to ascertain whether this part of the cycle comes before or is associated with already completed nests as it is in some of the typical weavers (Ploceinae).

Turning now to the next group, the weaver finches (subfamily Passerinae), which group includes the ubiquitous house sparrow (*Passer domesticus*) and its relatives, we find a different range of nest types. Some, like the house sparrow, build fairly bulky, formless, untidy nests in trees, on ledges, cornices of buildings, even in holes in trees, and other elevated sites (never on the ground). When built in the branches of a tree the nest usually is domed with an entrance on one side, and fairly abundantly lined with feathers and other soft materials; when built in a hole the lining is much reduced as is

the rest of the nest structure. The birds are multiple-brooded; both sexes take part in nest building and in caring for the young.

Although the nests are not such as would, in and of themselves, suggest that their makers were overly involved in building activities, there is evidence that in a closely related species, the Cape sparrow of South Africa, *Passer melanurus*, the birds use the nests throughout the year as sleeping places " . . . especially in winter, when nests with more warm material are often specially built for the purpose" (Roberts, 1940, p. 334). In other words, in this species we find some indication of nest-building activity outside of the breeding season. Whether this is true for other forms of the genus is not known.

To return to the house sparrow, the reproductive behavior cycle, as reported by Jourdain and Tucker (1938, pp. 157-158), is quite peculiar and is still in need of further study before it can be properly interpreted. The—

. . . prominent feature of breeding-season is noisy display, in which sometimes one, but commonly several males hop with loud chirpings, round female with elevated bill and tail and drooping wings, but merely elicit pecks from irritated hen . . . Whole performance commonly ends with sudden dispersal of participants and appears unconnected with coition or even pairing. Gengler relates latter to rough-and-tumble scimmages between several males without display, female commonly becoming involved as well, though selection of mates as result of these tussles seems not very clearly demonstrated. Coition is normally solicited by female with drooping wings and twittering note, without display by male, and may be repeated as many as a dozen or fifteen times in succession. Same observer states that both mated and unmated birds of both sexes are involved in displays, but that mated males display only to other females, never their own. He interprets display as relief of former genuine courtship, now functionless except as outlet for persistent display instinct . . . exceptionally coition may be preceded by typical display of male without usual solicitation of female.

There is evidence, as well, that the species has a polyandrous or promiscuous tendency, and Thompson (quoted by Jourdain and Tucker) considers the noisy displays are explained partly by this tendency, and partly by the males coming into breeding condition before the females.

Other members of the subfamily, such as the yellow-throated sparrows of the genus *Petronia*, the rock sparrows of the genus *Gymnoris*, and the gray-headed sparrow, *Passer griseus*, appear to nest chiefly if not wholly in holes in trees, in old woodpecker or barbet holes, or even in suitable natural holes of not too large a size. They generally line these nesting holes with fibers and feathers. The gray-headed sparrow has adapted itself to human habitations and frequently nests under the eaves of buildings. The chestnut sparrow, *Sorella emini*, not infrequently makes use of old nests of other weaverbirds although it does at other times build for itself.

The absence of adequate data on the members of this group, other than the house sparrow, makes it impossible to generalize on any broad

scale or sure foundation. It is safer, then, merely to summarize the picture in the one relatively well-known member. The picture of courtship display is markedly altered from what we are in the habit of considering normal for most passerine birds—males displaying to any females but their own mates; females apparently soliciting rather than permitting coition, a precarious monogamy with a tendency toward polyandry and promiscuity.

The scaly weavers of the genus *Sporopipes* form a subfamily by themselves, the Sporopipinae. They are not too well known, but I have found them in very loose flocks or small assemblages in the dry thornbush veldt of the Transvaal, where they feed on the ground like the Passerinae. The South African species (*Sporopipes squamifrons*) breeds during the southern winter as a rule, but at times during the summer as well, suggesting a not too well delimited nesting time. These birds are not colonial breeders, but build their roughly globular nests of grass stems and fine twigs, with a fairly pointed lateral entrance, in the middle of the dense thorny branches of shrubs and low trees. Two nests that I found were less globular than published descriptions indicate is usual. They were somewhat similar to the untidy structures of the house sparrow, but smaller, slightly more compact, and less irregular in shape. In my field notes I described them as horizontal cylinders rather poorly closed at one end, and made of grasses, fine twigs, straws, etc. One nest containing three eggs was being very timidly guarded by two of the birds, presumably a pair (the sexes look alike). The birds would not stay near the nest while I was close to it, but returned to it as I walked away. Nothing seems to be on record concerning courtship, mating, or territorial behavior in any of the scaly weavers.

We now come to the subfamily Viduinae, the indigo birds and the widow birds, containing a dozen species, three of which are definitely known to be parasitic and the others are suspected of having similar breeding habits. This group is somewhat intermediate between the Ploceinae and the next subfamily, the Estrildinae. Like the members of the Ploceinae, the Viduinae take 2 years to acquire adult plumage, and do not breed until then (the Estrildinae breed when 1 year old, as do the majority of small passerine birds). The adult males have a breeding plumage in which they are very different from the brown, streaky hens and year-old birds, the former of which they resemble in the nonbreeding plumage. (The Estrildinae do not show any seasonal plumage change as a rule.) The best known of the Viduinae is the pin-tailed widow bird, *Vidua macroura*, and the following description of its habits is taken largely from my field notes coupled with pertinent data in the literature.

Vidua macroura is a gregarious bird and is usually seen in flocks of from 5 to 50 birds, depending on the season. In the breeding season

in South Africa, where seasons are definite, the flocks tend to break up and the birds pair off more or less. Yet it is not uncommon to see small flocks all through the breeding season. Such flocks usually contain but one full-plumaged male and the rest of the birds are in the brown hen type of plumage. In some cases I shot into the flocks and found that the brown birds were year-old males, but in two cases the birds proved to be females with fairly enlarged ovaries. It seems, therefore, that this bird is somewhat polygamous, although I should judge from most of the cases I have observed (and they are many) that it is frequently, if not usually, more or less monogamous. In equatorial Africa all the individuals of the species in any one locality do not breed at the same time and these flocks usually contain a breeding pair and either year-old birds or nonbreeding adults. The lack of definite seasons complicates things superficially to the extent that the apparent state of affairs has no real relation to the actual conditions.

This widow bird is largely terrestrial in habit and gathers most, if not all, of its food on or near the ground. However, in Natal, at least, during the southern winter the birds go about in large flocks and spend much time in the trees, where they act and sound not unlike small finches such as the North American redpoll, *Acanthis linaria*. They are by no means confined to trees and are found in tall grass and in reeds along stream banks. During the breeding season the males often use isolated trees as perches from which to sing and to watch over their territories, but the birds spend by far the greatest part of the time on the ground.

On November 24, at Woodbush, Transvaal, I saw an adult male in full breeding plumage. It was perched on a bush in an open grassy field, and as I approached it flew off to a nearby bush and then to another not far off as I came close again. It made a small circling flight and came back to the original bush. On and off during the rest of the day I found it there each time I visited the spot and found by repeated trials that it could not be induced to leave it. It had definitely established its territory there, and apparently the bush in which it was first found was its singing perch. The next day I spent a couple of hours watching it and tried to make it fly off, but it would not go more than a hundred feet and then circle back gradually. There was a single hen bird in the immediate vicinity. I shot the male and found the testes were much enlarged. The plumage was still very fresh; in fact the long central rectrices still retained a little of their sheaths and one of them was so loose that it came out when I skinned the bird.

In the same region I watched two other males that were established in their individual territories. One of them was watched for 3 successive days and was apparently without a mate as yet. It had a

territory about 400 yards in diameter, considerably larger than that of the first male, but more open, less bushy, and probably contained possibilities of no greater number of nests to parasitize than the other. The third and last male had a smaller breeding area and was usually accompanied by three or four brownish henlike birds. I shot one of these birds and found it to be a male—a year-old bird in first nuptial plumage.

The courtship displayed was first observed at Woodbush, Transvaal, on December 1. The male flew up from the ground and hovered about 2 feet in the air directly over a female, with his body feathers slightly ruffled and his wings beating rapidly. With each wing beat the four long rectrices were violently jerked and made to stream boisterously over the female, much after the cascade type of tail display of *Coliuspasser ardens* and *Coliuspasser procne*.

On another occasion, in equatorial East Africa, I saw a male display to a female that was perched in a thorn tree. The display was similar to the one already described; the male danced in a stationary position as though suspended in midair a couple of feet above the female. On still other occasions I watched males courting when there were several of the brownish hen-feathered birds present. In all such cases I noticed definitely that the male tended to confine his attentions to one particular bird. It seemed as though there was but one female and that the other brown birds were year-old males. In one case I shot the whole band (five brown birds) and found that one was a female in breeding condition and the rest were young males.

Inasmuch as this widow bird is parasitic in its breeding habits it is interesting to compare it with the cowbirds (*Molothrus*) of the Americas. The chief difference seems to be in their sexual relations. Both are more or less monogamous but the *Vidua* tends toward polygamy while the *Molothrus* tends toward polyandry.

The vocal efforts of this species are not remarkable. The usual call notes are weak, high, but sharp *tsips*, something like the weaker notes of the redpoll (*Acanthis linaria*). When a band of birds calls simultaneously and rapidly they produce a light twittering chorus. The song is a rapid but modulated repetition of the call note and usually consists of from 5 to 10 syllables and occasionally more. It is given in flight as well as when at rest. Curiously enough, I never heard a male sing while going through his display dance before a female.

As is well known, this species is parasitic in its breeding habits; i. e., it lays its eggs in the nests of other birds and leaves them to their care. *Vidua macroura* is not the only ploceid exhibiting this habit—*V. regia* and *V. paradisea* and, as we have already noted, *Anomalospiza imberbis* are also parasitic, and probably the other species of *Vidua* will in time be found to be parasitic as well. *Vidua*

macroura is parasitic chiefly on waxbills and generally lays but one egg in a nest. I have seen sets containing two, three, and even, four of the widow bird's eggs along with those of the victims, but such sets are not usual. The eggs are pure white and differ from those of the common fosterers only in size.

The following birds have been found to be parasitized by *Vidua macroura*:

Lonchura scutatus
Estrilda astrild
Estrilda subflava
Estrilda melpoda
Estrilda massaica
Estrilda melanotis

Estrilda rhodopyga
Estrilda delamerei
Lagonosticta senegala
Lagonosticta rubricata
Amauresthes fringilloides
Colius passer ardens

The incubation period is 12 days.

The breeding season in South Africa is late in the southern summer—January, February, and early March, sometimes earlier. In Kenya Colony the species breeds during both the short and the long rainy seasons. The short rains come in November, December, and January; the long rains in April, May, June, and July. As one goes northward the rains shift to later in the calendar year; thus in the southern Sudan the long rains extend into September and start correspondingly later than in Kenya Colony.

The young *Vidua* does not always crowd out or starve out its nest mates (at least in the few cases I watched) as do the young cuckoos and cowbirds in so many cases, but all grow up together. Fully fledged young *Vidua macroura* are often found in flocks of young waxbills after leaving the nest but they do not remain long in these assemblages. Before they get ready to molt (postjuvenal molt) they form flocks of their own. I have seen as many as 15 or 20 young pin-tailed widow birds together. Frequently one or two adult birds, often males in breeding plumage, are found in these flocks.

My observation on *Vidua regia*, the shaft-tailed widow bird, *Vidua fischeri*, the straw-tailed widow bird, and *Vidua orientalis*, one of the indigo finches, while much less complete than those on *Vidua macroura*, also indicate that the superficially apparent polygamy is actually not real, that while one male in adult breeding plumage may be accompanied by a small flock of brown henlike individuals, most of the latter are immature birds of both sexes and only one in a group may be an adult female. In the case of the straw-tailed widow bird, *Vidua fischeri*, I once observed what seemed to be a territorial fight between two males in full breeding plumage.

To summarize the behavior-pattern cycle in the Viduinae, we may characterize it as follows: apparently monogamous and solitary(?), but solitary only with respect to its own age group (adults), not solitary



1. COLONY OF *POLOCEUS CUCULLATUS*
(From Chapin, Bull. Amer. Mus. Nat. Hist., vol. 37, 1917.)



2. COLONY OF *POLOCEUS NIGERRIMUS*



1 NEST OF *PHILETAIRUS SOCIUS*



2 UNDER SIDE OF NEST TO SHOW INDIVIDUAL NEST
ENTRANCES



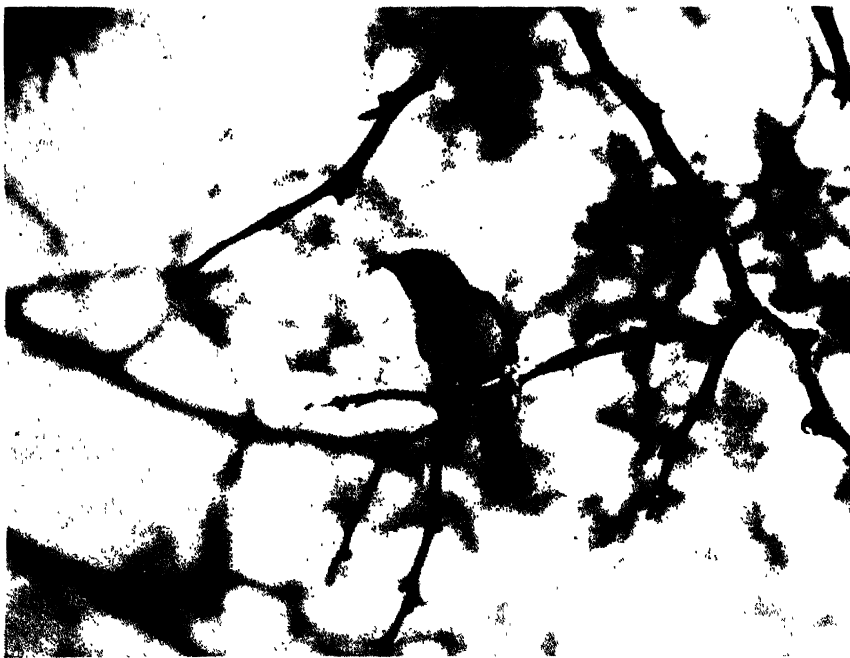
1. NEW AND FAIRLY SMALL NEST OF PHILETAIRUS SOCIUS



2. ONE OF THE BUILDERS UNDER A CORNER OF THE GIGANTIC COMMUNAL NEST



1. A VERY LARGE OLD NEST OF PHILETAURUS SOCIUS, PARTS OF WHICH HAD
FALLEN DOWN BY THEIR OWN WEIGHT



2. THE SOCIAL WEAVERBIRD, PHILETAURUS SOCIUS



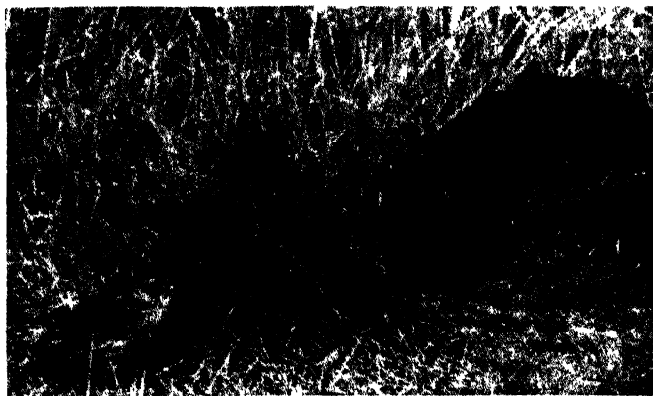
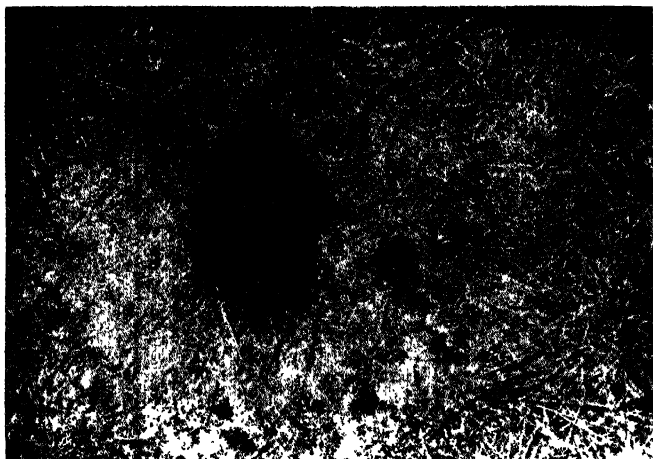
1. NEST OF *PLOCEUS OCULARIUS*

(From Chapin, Bull. Amer. Mus. Nat. Hist., vol. 37, 1917)



2 NEST OF *EUPLECTES FLAMMICEPS*

(From Chapin, Bull. Amer. Mus. Nat. Hist., vol. 37, 1917.)



Upper, dancing ground of *Coliuspasser jacksoni*; middle, male *Coliuspasser jacksoni* on its dancing ground; lower, male *Coliuspasser* displaying to female on dancing ground.

(All photographs on this plate from Van Someren, Journ. East Africa Nat. Hist. Soc., vol. 18, 1945.)



1. CUCKOO FINCH, *ANOMALOSPIZA IMBERBIS*
(From Shelley, Birds of Africa, vol. 4, 1905.)



2. YOUNG *ANOMALOSPIZA* BEING FED BY *PRINIA FALVICANS*
(From Roberts, Ann. Transvaal Mus., vol. 5, 1917.)



1 COLONY OF PLOCEUS SPILONOTUS



2. NEST OF PRINIA FLAVICANS WITH THREE EGGS OF ITS OWN AND ONE OF VIDUA REGIA

as far as immature "hangers-on" are concerned; courtship display well developed in all species; nest-building, incubation, and rearing instincts completely lacking in three members (*V. macroura*, *paradisea*, and *regia*) and probably in the others as well. The young of the three known parasitic species do not seem to evict or to starve out their nest mates of the host species, but may grow up in apparent amity with them. Roberts (1939, pp. 106-107) finds that while this is so, the female parasite usually destroys an egg of the host when depositing its own in the nest, but no such observations have been published. Usually there is but a single egg of the parasite in any one nest, but Roberts has found one instance where "five eggs of the common waxbill were all replaced by eggs of the Pin-tailed Widow-Bird." Delacour and other writers have implied that the Viduinae are parasitic chiefly on waxbills, and even go so far as to suggest that each of the Viduinae has its particular Estrildinae host species, but this is by no means definitely established. Thus, the pin-tailed widow bird is known to parasitize at least nine species of *Estrilda* and *Lagonosticta*, and two ploceine weavers, *Coliuspasser ardens* and *Amauresthes fringilloides*, while there is some evidence that *Vidua regia* lays its egg in the nest of a warbler, *Prinia flavicans*.

The last subfamily of weaverbirds, comprising the waxbills, grass finches, and mannikins, is the Estrildinae. Delacour (1943, pp. 71-72) has recently summarized the characteristics of this group as follows:

Small weaver-finches of highly specialized color pattern, never showing a primitive streaked sparrow-like brown plumage and horn-colored bill; sexes alike or different; immature always different from adult females. No eclipse plumage in males, with one exception. Nestlings always showing brightly colored, swollen spots, lobes or bands at the gape, and an ornamentation of the tongue or palate, consisting of spots or lines. Eggs numerous and always white; nests globular with a side entrance, but not woven. Young birds become adult within a year of their birth and are then able to breed, while it takes two years for young Viduinae and Ploceinae to mature. Peculiar song and courtship variable but consistent, in a general way, in large groups of genera. Ten primaries in the wing, the first being very short and falcate, with the exception of two genera (*Clytospiza* and *Spermophaga*) where it is moderately long, not parasitic.

This large group is composed of three natural subdivisions: the waxbills, chiefly found in Africa, but with one genus in Asia; the grass finches, found in Australia and some of the islands of the south Pacific; and the mannikins, found in Africa, Asia, and Australia. The Estrildinae never weave elaborate nests like the Ploceinae but construct roughly globular nests of grasses and leaves, with the entrance on one side, and which are usually built near or on the ground, in the grass, or in bushes and low trees. The nests are very large for the size of their builders. A number of species frequently use old nests of other weavers, but usually do a certain amount of work on the

nests themselves, such as adding to or rearranging the lining. Thus, the bronze mannikin, *Lonchura cucullatus*, sometimes builds its own nest, but often breeds in old nests of other weavers, particularly of species of *Ploceus*. At Kaimosi, in western Kenya Colony, I found a rather untidy, loosely constructed nest of dried grasses and plant fibers, lined with grass seed-heads and feathers; it contained four white eggs and was evidently the nest of a pair of these mannikins, which were constantly seen on or about it. On the other hand, a day later I saw a *Lonchura* enter an old *Ploceus* nest, and, wondering what the bird might be doing there, I cut down the nest and found in it two eggs exactly like those found in the other nest the day before. The bird acted in a very excited manner as I examined the nest. Jackson (p. 1473) also records that this species breeds in old nests of *Ploceus reichenowi*, which it lines with grasses. Other Estrildinae known to use old nests of other species not infrequently are the silverbill, *Lonchura cantans*, the cut-throat finch, *Amadina fasciata*, the red-headed finch, *Amadina erythrocephala*, the common waxbill, *Estrilda astrild*, the zebra waxbill, *Estrilda subflava*, the lavender waxbill, *Estrilda perreini*, and the cordon-bleu, *Uraeginthus bengalus*.

Aside from the fact that nest building in many of the Estrildinae is not so fixed in its pattern but that the birds may either build new nests for themselves or make use of old nests of other species (often very different in design from those their own species would construct), it is worth noting that in a good number of species the males take part in the task of incubating the eggs. Thus, in writing of the zebra waxbill, Jackson (p. 1517) goes so far as to say that ". . . as is generally the case with Waxbills, the males assist in incubation." Information on the courtship habits and sexual relations of the Estrildinae is still rather scanty, at least as far as significant and reliably worked-out details are concerned, but what data there are indicate nothing unusual in either respect. The birds appear to be monogamous, and, as is so frequently the case with species in which the sexes look alike, the courtship antics do not show any peculiar or marked developments.

In review, then, the great family of weaverbirds exhibits an astonishing range of diversity and variety in the mode of expression of the different parts of the reproductive behavior cycle. In the beginning of the breeding time we find everything from marked fragmentation of wintering flocks into pairs, to year-round gregariousness, and in courtship from a pattern that comes prior to nest building to one that follows the completion of the nests by the males, from solitary antics to elaborate display on special dancing grounds, and, on the other hand, to almost none at all, or, as in the case of the house sparrow, to barren but promiscuous displaying by mated males, seemingly

devoid of direct reproductive function, coupled with apparently monagamous coition-inviting display by mated females. Nest building may vary from solitary to highly communal, and to none at all, and even to parasitism, from slovenly put together masses of material to amazingly fine and intricate weaving, or huge, communal superstructures, or may be reduced to merely relining a disused nest of another species or to lining a hole in a tree. Nest construction may be done entirely by the male, by both sexes, or largely by the female, or may be omitted entirely. Sexual relations vary from solitary monogamy or social monogamy to polygamy, polyandry, and to apparent promiscuity. Incubation in some species, or groups of species, is performed solely by the hens, while in others the cocks share the task with their mates, or, in the case of still others, neither sex takes any care of the eggs, but are parasitic. The members of the subfamilies Ploceinae and Viduinae do not come into breeding condition or acquire adult breeding plumage until they are 2 years old; the members of the other groups breed when 1 year old; this in itself is a profound difference. In some forms of the Viduinae and Ploceinae it permits a type of breeding-season gregariousness, although only a single adult male and female are usually involved in each little flock.

Few, if any, families of birds offer such a bewildering array of variations of the parts of the annual cycle, and I cannot help but wonder if some of these variations may not have been due originally to the extremes to which, in previously established variations, some of the stages had been carried. At least the situations created by some of these extreme developments seem to have been propitious for further and even quite contrary subsequent changes.

Paradoxical as it sounds, it is possible that the excessive development of the nest-building habit may actually have been a contributing factor in the origin of the complete absence of nest building and egg care that we know as brood parasitism. In cases of extreme indulgence in nest construction such as we find in the social weaverbird (*Philetairus socius*) and some of its relatives (*Plocepasser* etc.), the huge bulky structures are added to, chiefly by the males, all through the nonbreeding season. By the time the birds are ready to make their own individual nest tunnels in the already existing superstructure they are not acting very differently from birds that make use of old nests of other species which they then repair. In the case of the numerous species of typical weavers (Ploceinae) in which the not yet breeding males construct many nests, the subsequently mated females are again in a not dissimilar position of taking over nests which they themselves have not built, and relining them and breeding in them. It seems that Ali (1931) must have had some such thought in mind when he noted that Baya weavers occasionally laid eggs in disused

nests of others of their own kind instead of making new ones for themselves, as this prompted him to raise the following argument:

If the bird laid in disused nests it would only succeed in avoiding the labour of building, but would still have to incubate the eggs itself. If on the other hand it was successful in slipping into an unguarded Baya nest whence the brooding hen had gone (as actually happened on September 18) and in laying its eggs there, it would be, quite involuntarily, but with good effect all the same, compelled to retire on the return of the legitimate occupant, leaving its egg to be hatched by the Baya. Would such a process not tend, in course of time, to develop into, and establish, a habit of systematic and voluntary parasitism as has been observed in some African weavers?

In this connection it may be recalled that Lynes (1924, p. 661) found that in nesting colonies of several species of African weavers related to the Baya, studied by him in the Darfur Province of the Sudan, many nests contained one or two extra eggs of the same species as the host, but recognizably distinct by virtue of different color or state of incubation, in other words, eggs that probably were laid by other individuals of the same kind. It seems then, both in Asia and in Africa, that not infrequently female weavers, ordinarily using nests they have not built themselves, may lay an occasional egg in a nearby nest of their own species.

The Viduinae are, as stated earlier in this paper, intermediate between the typical weavers (Ploceinae) and the waxbills (Estrildinae). In many species (perhaps the majority) of the former group, and also in a good number of forms of the latter group, the hens breed in nests, the actual construction of which has been foreign to their experience and their efforts; in many forms of the latter group, and at least some members of the former subfamily, the care of the eggs is taken over, at least in part, by the cocks.

The parasitic mode of reproduction occurs, as far as known, in five widely separated and quite unrelated families of birds—the ducks, the cuckoos, the honey-guides, the weaverbirds, and the hang-nests (cowbirds). There can be little doubt that the development of brood parasitism has taken place independently in each of these five groups, and it is not without significance, or at least suggestive value, that this highly aberrant reproduction pattern has developed among the small passerine birds (generally considered to be the most highly evolved of all the birds) in those two families some of whose members have carried the habit of nest building to its highest and most complex development. It is all the more noteworthy that in the weaverbirds, a larger group than the hang-nests and one with greater diversity of behavior patterns, the parasitic habit has developed in two subfamilies, apparently [independently—the] cuckoo finch, *Anomalospiza imberbis*, in the Ploceinae, and in the members of the Viduinae, three of which are definitely known to be parasitic, and the rest of which

are strongly suspected of having the same habit. Many more details have still to be learned of the annual cycle of behavior patterns in these birds before it may be possible to attempt to determine the precise causes and the subsequent evolutionary paths that twice in the history of the weaverbirds have lead from nesting and incubation and caring for the young to a state of brood parasitism.

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NEW ZEALAND, A BOTANIST'S PARADISE

BY EGBERT H. WALKER

Associate Curator, Department of Botany, U. S. National Museum

[With 10 plates]

INTRODUCTION

The wisest traveler learns as much as possible before a trip, sees all he can during his journey, and corrects and enlarges his knowledge by further reading and inquiry after returning home. This article is the outgrowth of the author's short but full visit in New Zealand, which was ideal in nearly every respect except for lack of advance knowledge of the country, especially of its botany. It suggests what the writer would have liked to know in advance but had to learn on the trip and after it. The suggestions given here for further reading may be of interest, not only to the fortunate few who will visit New Zealand in person, but the greater number who may do so vicariously by reading and by listening to those who have gone.

The plants of New Zealand can hardly fail to gain the attention of the visitor, and the student of New Zealand will find abundant reference to them in his reading. People in an industrial country may ignore the plant life, but those in an agricultural land like New Zealand cannot escape the imprint of the vegetation on their lives. New Zealand is a land of enthusiastic and competent amateur naturalists, and its professional botanists are outstanding. The visitor will find a local naturalist in nearly every town or center, who is eager to share his specialties with the stranger and to show him the offerings of the field. The traveler to New Zealand will probably first meet the introduced flora which dominates the landscape in the inhabited parts. Only when he visits the more remote and undisturbed areas will he see many of the native plants. If he has an economic or agricultural bias, probably the grasslands, the backbone of New Zealand's economy, will impress him most. (See pl. 9.) If he is conservation-minded, the sight of the vast area of shrubland and fernland (*Pteridium aquilinum* var. *esculentum*) will make him painfully aware of man's destruction of the native forest. But the soul of the pure botanist, undisturbed by problems of economics and con-

servation, will be stirred most as he enters the forest or "bush" where abounds the native New Zealand flora, so rich in plants found in no other country—that is, the endemic species. (See pls. 2 and 3.) Besides the grassland, scrub, and bush he will see other plant formations. The extensive plantations of trees, all planted in rows of uniform age, are very impressive. The species so grown are all exotics, that is, not native to New Zealand, the principal one being the Monterey pine (*Pinus radiata*), a useless tree in its native California, but here by far the most economically important tree to be found. Not only does it occur in plantations, but it is to be found almost everywhere as a hedge tree or windbreak (pl. 9, fig. 1) and even as a naturally planted weed invading wasteland.

It is essential in understanding the peculiarities of the flora of New Zealand to know its location and climate as contrasted with that of more familiar areas. The vegetation or the major plant formations will then be discussed, after which the flora or the elements which compose the vegetation will be taken up. Finally some consideration will be given to the past and present study of botany in the country.

LOCATION AND CLIMATE

New Zealand extends from about the 34th to the 47th parallel south latitude, a distance of about 900 miles. (Fig. 1, and fig. 2, p. 333.) It consists essentially of three islands, North, South, and Stewart Islands, with a few small nearby islands or islets. There are several outlying island groups, politically and biologically part of New Zealand, of much interest, but they are not included in this discussion. For vivid geographical comparison, suppose the three main islands of New Zealand were inverted and superimposed on North America at a corresponding latitude, with the North Cape of North Island at Cape Lookout about the center of the Atlantic coast of North Carolina. Then the South Cape on Stewart Island would lie north of Quebec in Canada. The East Cape at the end of the Grisborne Peninsula of North Island would be in southern West Virginia, and Mount Egmont at Harpers Ferry, W. Va. Wellington, at the southern end of North Island, would be in west-central Pennsylvania, and Christchurch on the east side of South Island would be on the shore at the east end of Lake Ontario. Both areas are in temperate zones of the earth's surface, but their climates are in striking contrast. Eastern North America has a continental climate with extremes of temperature and a moderate, irregular precipitation. New Zealand, however, has a strong oceanic climate with far milder temperatures throughout and a much smaller difference in temperature between the northern and southern ends and between winter and summer. The precipitation is fairly evenly distributed throughout the year, although it varies from place to place. New Zealand owes its climate to the unifying

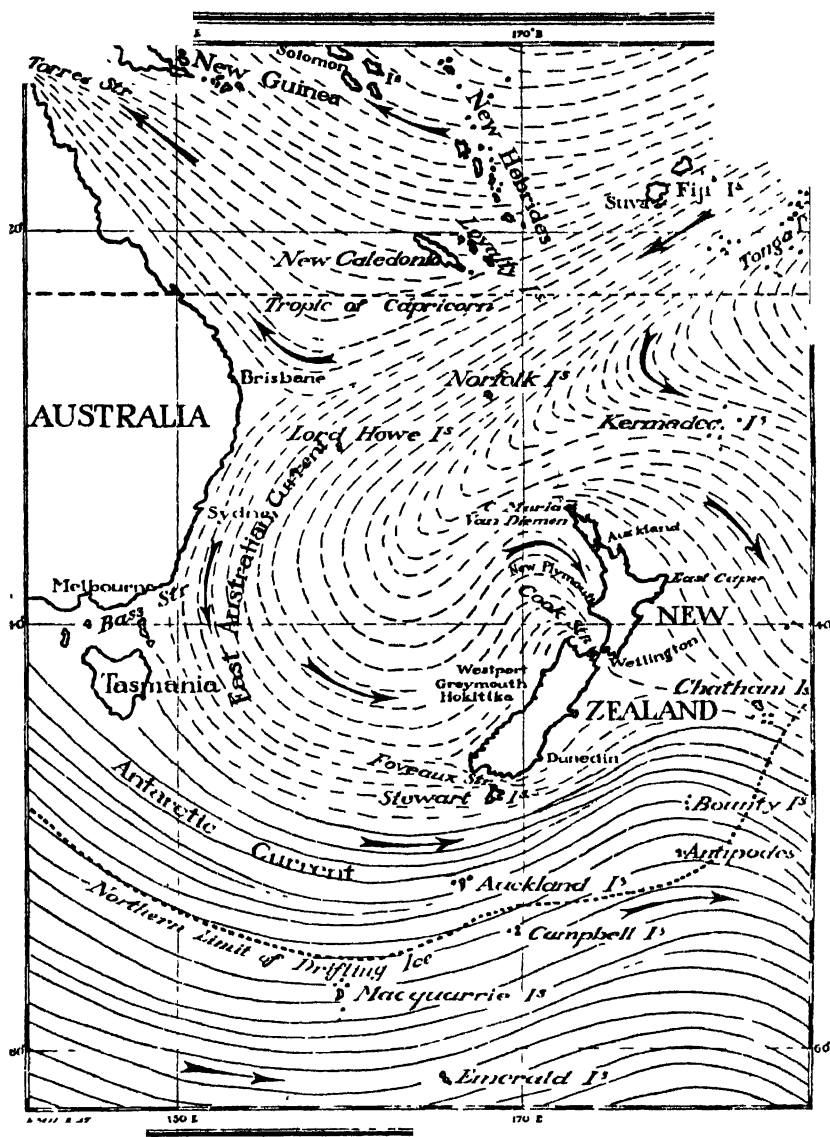


FIGURE 1—Chart of Tasman Sea showing deflection of the cold Antarctic drift by the warm East Australian current from the Tropics. (From W. C. Davies (12).)

influence of the warm Tasman Sea on the prevailing westerly winds which blow over it from Australia, over a thousand miles away. In its oceanic climate lies the explanation of many of its vegetational contrasts with other countries.

The vegetation in northern New Zealand is far more tropical in appearance than its geographical counterpart in North Carolina.

This "subtropical" aspect of the forests can be seen even in northern South Island and grades into the characteristic features of the dense temperate rain forests of the west coast of South Island. The southern-beech forests of *Nothofagus* in the south are clearly Temperate Zone forests. (See pl. 1, fig. 2.)

The mountains in New Zealand cause more changes in the climate from place to place than does the latitude. The mountain ranges and plateaus of North Island lie mostly east of the center. They are largely volcanic and influence the vegetation not only through their effect on the winds and moisture but also on the soil. The volcanic ash and pumice readily absorb more moisture, much of which seeps away beyond the reach of the plants growing on the surface. Mount Egmont is a majestic isolated volcanic cone on the west coast with vegetation in characteristic altitudinal zones from sea level to the perpetually snow-covered summit.

In South Island the rugged Southern Alps parallel the west coast and thrust their peaks far into the zone of permanent snow. (See pl. 7, fig. 1.) Their highest peak is Mount Cook, its summit 12,349 feet above the Tasman seashore less than 24 miles to the west. They are formed by erosion of uplifted land rather than volcanic activity and are composed largely of friable greywacke rock. (See pl. 7, fig. 2.) These ranges drain the prevailing westerly winds of most of their moisture. Thus the west coast has a heavy rainfall of around 200 inches a year, while on the plains of the eastern leeward side there may be as little as 20 inches. The highest annual rainfall yet recorded is 228 inches at Puysegur Point on the west coast, and the lowest, 13 inches, in Central Otago only 150 miles away. Dense rain forests cover the steep western slopes and the narrow coastal plain below, whereas on the east are the natural grasslands and the broad cultivated plains. In Central Otago is a semidesert area. The transition from heavy rain and dense forest to sunshine and almost barren eroding slopes may be made in a surprisingly short time in driving over the divide. Other ranges and hills, especially the Kaikora Ranges in Marlboro and those in the rugged Banks Peninsula, interrupt this picture and diversify the ecological conditions and vegetation. Thus New Zealand has a great variety of distinctive plant formations in a remarkably small space, a fact which makes botanizing a most interesting and relatively easy occupation. The climate of New Zealand has been presented by Kidson (16, 17).¹

THE GRASSLANDS

The grasslands of New Zealand are the foundation of its agricultural economy, and one is sure to be impressed by their extent and

¹ Numbers in parentheses refer to the bibliography.

variation. They are of two kinds: first, the original tussock grasslands of native species (pl. 9, fig. 2), and second, the pastures with a sward formed of introduced species (pl. 9, fig. 1). The history of New Zealand is largely the story of man's replacement of the native bush with pastures and the exploitation of the native grasslands in feeding his flocks of sheep. In the ashes of the bush he planted grasses and began the process of adapting the sward-forming techniques, so well developed in his native England, to the conditions of this new and promising land. He fought a continual battle with the few native plants with weedlike tendencies and the more numerous and generally more vigorous exotics, which he intentionally or unintentionally brought from the far parts of the earth. From early blunderings he has now developed the technique of sward growing to a very advanced degree, and agricultural progress or deterioration in large parts of North Island and certain regions of South Island depends on the composition and condition of this pasture sward. Much land formerly covered with fern, scrub, or blackberry is now grass-covered, with a high sheep-carrying capacity. It was a most enlightening experience to see the work of the Animal Research Station at Ruakura near Hamilton in Auckland Province, in breeding and mixing strains of grasses, on which, with proper rotation, an amazing number of sheep can graze throughout the year without additional feed. The various types of these artificial grasslands of North Island have been carefully mapped and analyzed in a publication by Madden (19). Something of the history and significance of these grasslands can be gleaned from the account written by an English[†] agronomist, Stapledon, who visited Australia and New Zealand in 1926 (25). The planted pastures of South Island, developed by essentially the same means, are well described in Hilgendorf's ecological survey of the grasslands (13), which supplements Madden's.

The natural grasslands are very different from the man-made pastures. They occur most extensively in South Island, but smaller areas are to be found in North Island, especially in the central plateau. A relatively low rainfall with a cooler and more even temperature are among the principal factors governing the development of grasslands rather than shrublands or "bush." The plant composition of this formation varies considerably according to local conditions. Pastoralists generally recognize five tussock grasses. Two of them, snow grass (*Danthonia raoulii* var. *flavescens*)² and red tussock (*D. raoulii* var. *rubra*) are the tall tussocks, 3 to 6 feet high, while the short tussocks, 1 to 2 feet high, are the silver tussock (*Poa caespitosa*) and the hard or fescue tussock (*Festuca novae-zealandiae*). The blue tussock (*Poa colensoi*) is only 6 to 9 inches high.

[†] The names, both common and scientific, in general use in discussing these grasses vary considerably. This makes research on the grasslands rather difficult. Zotov (28) recognizes only four tussock grasses.

The history of the tussock lands is an almost continuous story of progressive deterioration due to overgrazing, burning, rabbit infestation, and increased wind erosion, land slip, soil creep, and water erosion. The present deserts in northern Canterbury, Marlboro, and Central Otago Provinces were grasslands when white settlement began, and the carrying capacity of most sheep runs is today far less than it was in the beginning. Everywhere one can see erosion that is of recent origin. A most definite sign of overgrazing in South Island is the excessive development of the scabweed, *Raoulia lutescens*. (See pl. 8, fig. 2.) Usually the rabbit population increases as the tussocks diminish and more open spaces are formed. This only accelerates the destructive process. It is important to keep in mind that the tussock grasses themselves are rarely grazed, except the new growth which springs up after they are burned over, which is traditionally done annually. The role of the tussocks is to furnish protection to the smaller grasses and other plants which grow among them and furnish most of the feed.

The tussock grasslands of South Island have been dealt with rather fully by Zotov (28) and recommendations presented for restoring these areas to production. First, annual burning must be eliminated or, if absolutely necessary to eliminate shrubby invaders, replaced with carefully controlled burning. The number of grazing animals must be reduced to the carrying capacity of the land and rotational grazing introduced in order to restore the fertility. When necessary, the tussock grass must be replanted with selected unpalatable strains or jordanons, and, when a protective covering is thus established, highly palatable strains of native species must be sown between the tussocks. Hardly any of these measures are now used by the sheepmen. It was most gratifying to have a glimpse of the Government's research work in tussock-grass restoration at its field station in Hutt Valley near Wellington. The work done there is preliminary to research and experimentation in the tussock country itself and will surely some day result in restoration of much depleted land. Probably some areas have gone almost beyond reclamation and will remain, as have so many other parts of the world, monuments to man's lack of foresight and self-control in seizing all the produce of the land rather than just its surplus.

SHRUBLAND AND FERNLAND

No traveler in New Zealand can fail to be impressed, and at the same time generally depressed, by the vast extent of land covered by shrubs and ferns. Unlike the grasslands, they bring no sense of well-being to man, and, compared with the forest, they at first seem botanically unattractive. But neither impression is wholly correct.

Shrubland is any plant community in which tall trees are wanting and shrubs dominate. The fern, which comprises the fernland, is the native variant of the world-wide bracken, *Pteridium aquilinum* var. *esculentum*, or *P. esculentum* of many authors. Fernland is here linked with shrubland because the fern reaches shrub size and the formation is as dense and impenetrable as the densest thicket of woody shrubs. Furthermore, this fern community is closely related ecologically to the other most extensive shrub community, that dominated by manuka³ (*Leptospermum scoparium* or *L. ericoides*—Myrtaceae) (pl. 5, fig. 2). Together these two cover more area than do the other shrub formations, of which there are many in very different habitats and of diverse composition, form, and origin. As in other lands, these shrub formations develop in response to certain natural conditions. These conditions may develop over a long period of time. When sudden changes occur favorable to the growth of a shrub community the formation is called an induced formation. Shrub formations follow certain volcanic eruptions and sometimes floods or places of excessive erosion. But more significantly they are man-induced, coming along after the forest has been destroyed with ax and fire, and grass has been sown on the ashes, or where man's fires and his overabundant greedy sheep have destroyed the natural grass cover. (See pl. 4, fig. 1.)

The manuka (*Leptospermum scoparium*—Myrtaceae) is a shrub or small tree with an amazing adaptability and persistence. It usually forms a community without the bracken or it may be variously mixed with this fern. It seems able to grow anywhere, wet or dry, in good soil or bad, and in heat or reasonable cold, but not in alpine conditions or deep forest shade. Its outstanding ability to thrive on poor soil makes it rush in where man has done his best to destroy the land. It is especially prominent on the gumlands of North Auckland, dug over and the fertility dissipated in the search for fossil kauri gum, desired as an ingredient in high-grade varnish. Manuka is extremely plastic in its response to its environment. Within this community there are some 81 other species of plants, many of them of great interest to the botanist, not the least being the bulbous-rooted New Zealand orchids. Manuka is an important source of fuel for man,

³ To the foreigner the widespread use in New Zealand of native Maori names for trees and other plants is somewhat disconcerting. Very often there is no other name, as for example, manuka for *Leptospermum scoparium* or kauri for *Agathis australis*. These names have often been made into the specific scientific names, as *taratare* in *Bellschmiedia taratare* and *tawa* in *B. tawa*. Another common practice of many New Zealanders is to use in speech a specific scientific name for a common name, as *macrocarpa* for *Cupressus macrocarpa*, *lawsoniana* for *Cupressus lawsoniana*, and *radiata* for *Pinus radiata*, the Monterey pine. Another disconcerting practice is the use of some common English name, such as pine, for something which a foreigner at least would hardly recognize as such. Native pine in New Zealand refers to species of *Podocarpus*. Thus the traveler is in a new nomenclatorial atmosphere. For popular names of New Zealand plants see Andersen (2) and Cheeseman (4).

and in its shade grow seedlings of many forest trees, which eventually rise up and wipe out this "nurse" species by overshadowing it. So the manuka shrubland fills a varied and not altogether harmful place in New Zealand's plant economy.

One cannot feel quite so resigned to the fernland, though one quickly does resign from the job of trying to penetrate it. Its adaptability and prolificness closely matches the manuka, but within its dense growth there are few if any other plants. Like the manuka, it cannot endure much shade or cold, and so is not a denizen of the forest and alpine or subalpine slopes. Man may burn its tangled fronds, but new ones rise quickly from the unharmed underground stems. However, overstocking with cattle which eat the tender young fronds catches the bracken in its "tendon of Achilles," and if the practice is persisted in, this scourge can eventually be conquered.

A third shrubland community of much prominence is not only the result of man-made conditions, but of man's introduction of plants. The English gorse, *Ulex europaeus*, was first brought, no doubt, to relieve man's nostalgic longing for the lovely English countryside and to lend color to the generally colorless New Zealand vegetation. But this was an imprudent act. From the hedgerows it spread easily to adjacent fields, dry, gravelly river beds, formerly forested hillsides, and pastures. It is quite indifferent to the quality of the soil. Large open spaces soon became impenetrable thickets. Man constantly burns it off, but fire seems only to improve the viability of its seeds and to impoverish the soil, which harms the accompanying fodder plants more than it does the gorse. Control over large areas by grubbing it out of the ground is hopeless in this land of limited labor and large demands on human resources. Handcuffed with this gorgeous yellow culprit are the broom (*Cystisus scoparius*—Leguminosae), the rose, and the blackberry, and several adventive shrubs from adjacent Australia, especially hakea (*Hakea acicularis*—Proteaceae). One American shrub of this category is the tree-lupine of California, *Lupinus arboreus*, brought as a sand binder and now spreading beyond its first plantings to other sandy and gravelly spots, not always according to man's wishes.

The term "scrub" is often applied to any shrub formation. In Australia it is erroneously applied to certain forest formations, but Cockayne (7) applies the term in a more restrictive sense to any community of divaricating, stiff, shaggy, and often spiny shrubs. Such shrubs have numerous extremely wiry or rigid, much interlaced branches and twigs which zigzag at a wide angle in every direction. The thickets they form are close, unyielding, and often cushionlike masses. To push ones way through this scrub is impossible and to travel over it is often a hazardous undertaking. The scrub is usually subalpine and is composed of various species of *Coprosma* (Rubiaceae),

Cassinia and tree-daisy (*Olearia*—Compositae), wild Irishman (*Discaria toumatou*—Rhamnaceae—pl. 6, fig. 1), and *Myrtus* (Myrtaceae), though altogether there are about 55 species in 18 families which have this divaricating habit.

The plant collector who makes pressed specimens almost meets his Waterloo when he tries to make a herbarium specimen to represent adequately such a plant. Some divaricating shrubs further thwart the collector by dropping their leaves, flowers, and fruits almost at the first gentle touch. The divaricating branches of pohuehue (*Muehlenbeckia astoni*—Polygonaceae) are pliant enough, but when a representative specimen has been warped into a plant press there is rarely a leaf or fruit left in situ, and a vivid supplementary description is needed to bring to the observer's mind any adequate concept of the original habit of the plant.

One will find various shrub formations in a wide range of habitats. Besides the extensive hillside formations of manuka and fern, and the subalpine scrub, this type of vegetation is often found on sea coasts (both rocky and sandy), wet lands, mineral lands, areas of volcanic ash and pumice, and wind-swept shores and mountain slopes. Its component species, growth forms, and adaptations to environmental conditions are of much interest. In some places associations of trees, dwarfed to shrub size by wind, salt spray, or soil influences, resemble and merge into shrub formations.

FORESTS

The principal natural resource in New Zealand when the *pakeha* or white man first came was its trees; at the present time it is its grass. But the white man could live only secondarily on the forest, so the trees had to go in order that he might provide for his primary need—food. Hence, this natural resource, which formerly covered almost the whole of North Island and much of South Island, was sacrificed at a rate hardly equaled anywhere else in the world. It took Europe four centuries to exploit its forests and America two centuries, but New Zealand accomplished this in one century. Although the extensive natural forests of the past are gone, the remaining fragments are sufficient to tell us a great deal about New Zealand's botanical history. According to Cockayne (7), 385 species of plants are characteristic of the forests. Of these, 99 are trees, 63 shrubs, 51 herbs, 26 grasslike plants, 88 ferns, 26 climbing plants, 15 epiphytes, and 13 parasites. Ninety percent are endemics. So it is in the New Zealand forest that a visiting botanist will find his greatest delight in becoming acquainted with the true New Zealand flora. If he arrives in North Island, as is most likely (and much regretted by the people of South Island), his first acquaintance will almost surely be with the rain forest, which is composed of many species of trees and shrubs of many genera and

families. (See pl. 3, fig. 1.) Later he will meet the strikingly different southern-beech forest, composed almost entirely of one or two species of *Nothofagus* and few shrubs. (See pl. 1, fig. 2.) There, if he is from the Temperate Zone of North America or Europe, the traveler will feel much more at home, although all the plants will be new to him.

The rain forest in New Zealand is clearly tropical in its origin and affinities; indeed, it is often designated as subtropical rain forest, although it lies entirely in the Temperate Zone. Its character is the result of the oceanic climate with its mild, rather uniform temperatures, and its abundant, evenly distributed rainfall, which assures a high atmospheric humidity throughout the year. The southern-beech forest of *Nothofagus*, however, is clearly temperate in origin, with its nearest affinity the *Nothofagus* forests in Patagonia, Tierra del Fuego, and southern Chile, on one side, and in Tasmania and adjacent Australia, on the other. This forest occurs in New Zealand in cooler and less humid regions than most of the rain forests. It depends more on ground water and thrives in a less humid atmosphere. All the forests in New Zealand are evergreen. There are a few deciduous trees but none of them are forest dominants, so there are no deciduous forests in New Zealand.

The rain forest is complex, the beech forest relatively simple. These two forests may be contrasted in part, as follows:

<i>Rain forest</i>	<i>Southern-beech forest</i>
Tropical in appearance.	Temperate in appearance.
Composed of many tree species in many genera.	Composed of one or two tree species in one genus.
Dense within.	Open within.
With several plant strata. ⁴	With only an open layer of shrubs between canopy and ground.
Bases of trunks often with plank buttresses.	Trunks without buttresses.
With many vines or lianas.	With very few vines.
Loaded with epiphytes.	With only a few parasites.
With many ferns.	With few ferns.

Each forest formation has various forest associations within it, these being quite complex in the rain forests and relatively simple in the southern-beech forest. The forest associations are named according to the dominant species within them, the principal associations in the rain forests being: (1) kauri (*Agathis australis*—Pinaceae), (2) mixed dicotylous-taxad,⁵ and (3) "white pine" or kahikatea (*Podocarpus dacrydioides*).

⁴ "Forest is piled upon forest."—Humboldt.

⁵ Cockayne's term for this forest association varies. It is called a mixed taxad forest (6) and dicotylous-podocarp forest (7). Species of New Zealand "pine," *Podocarpus* or *Dacrydium*, members of the yew family Taxaceae, are dominant or characteristic. There are also many trees of various families of dicotyledons, whose seeds have two cotyledons in contrast with the conifers which have several and the monocotyledons with only one cotyledon. The use of the term dicotylous rather than dicotyledonous is in conformity with Cockayne's usage (7).



1 LAKE FERGUS NEAR THE HOMER TUNNEL, WESTERN OTAGO, SOUTH ISLAND
Southern-beech (*Nothofagus*) forests clothe the mountains high up toward the snowy peaks of the Southern Alps.



2. SOUTHERN-BEECH FOREST (*NOTHOFAGUS FUSCA*), PARADISE, LAKE WAKATIPU,
OTAGO PROVINCE, SOUTH ISLAND

Without looking at the foliage one would think himself to be in a northern-beech (*Fagus grandifolia*) forest in temperate North America.



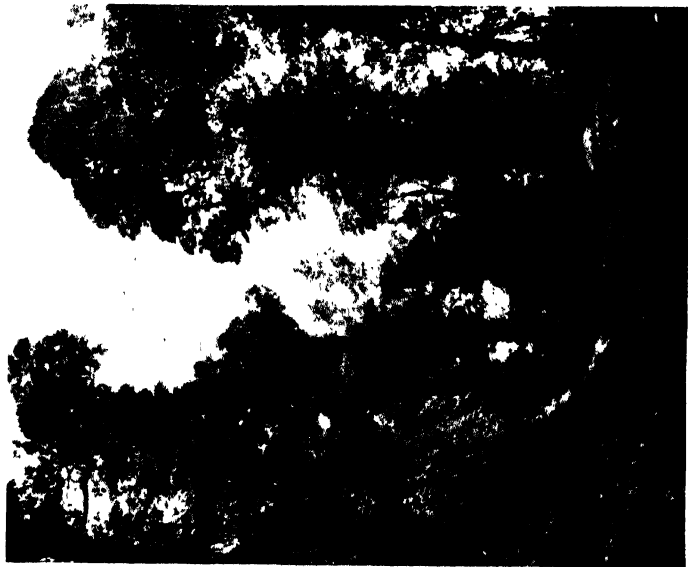
1. "TANEMAHUTU," A KAURI TREE IN THE WAIPOUA STATE FOREST, NORTH AUCKLAND, NORTH ISLAND

The bole is 14 1/2 feet in diameter and 68 feet high to the first branches. The crown is 100 feet and the spread of the crown 100 feet. Photograph by W. C. Davies. Courtesy Canadian Institute, Nelson.



2. A RATA (METROSIDEROS ROBUSTA) IN THE MIXED DICOTYLOUS-TAXAD FOREST

The rata usually becomes life as an epiphyte, reaches down to the ground, and envelops and strangles its host, and grows to be a huge forest tree. The climbing pandanus (left) and abundant epiphytes are characteristic of this dense jungle. (Photograph by W. C. Davies)



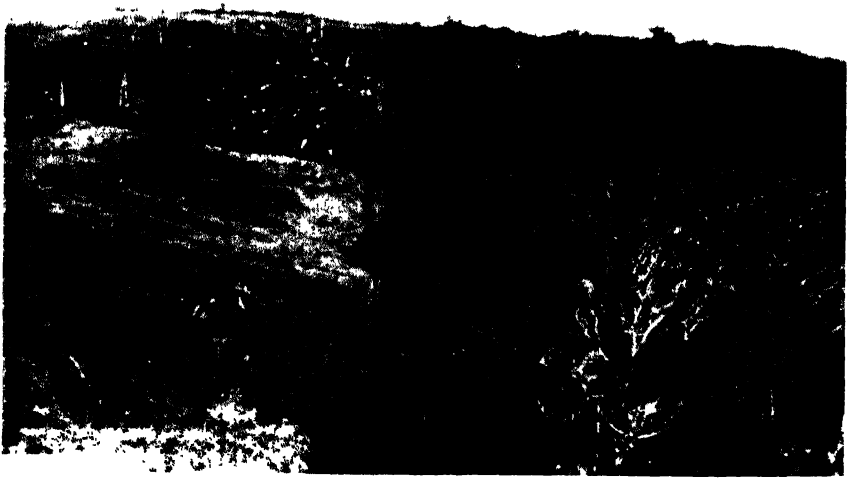
1. THE DENSE GROWTH IN THE MIXED DICOTYLOUS-TAXAD FOREST

Tree ferns, the nikau palms, fanas, epiphytes, and many tree species of all sizes comprise the several strata of this rich forest. Photograph by W. C. Davies.



2. A MEDLEY OF MOUNTAIN ROCK PLANTS. TARARUA RANGE, WELLINGTON PROVINCE, NORTH ISLAND

(*Clivia spectabilis*, left; *Enphrasia* sp. (center and foreground), and green vegetable sheep, *Riparia rubra*, covering a vertical rock, right. Photograph by J. S. Reid.)



1. EDGE OF WAIPOUA STATE FOREST, NORTH AUCKLAND, NORTH ISLAND

The untouched primary forest (right) formerly extended over the now cut-over stump, bracken, grass, and shrub covered sheep-grazing land (left). (Photograph by E. H. Walker.)



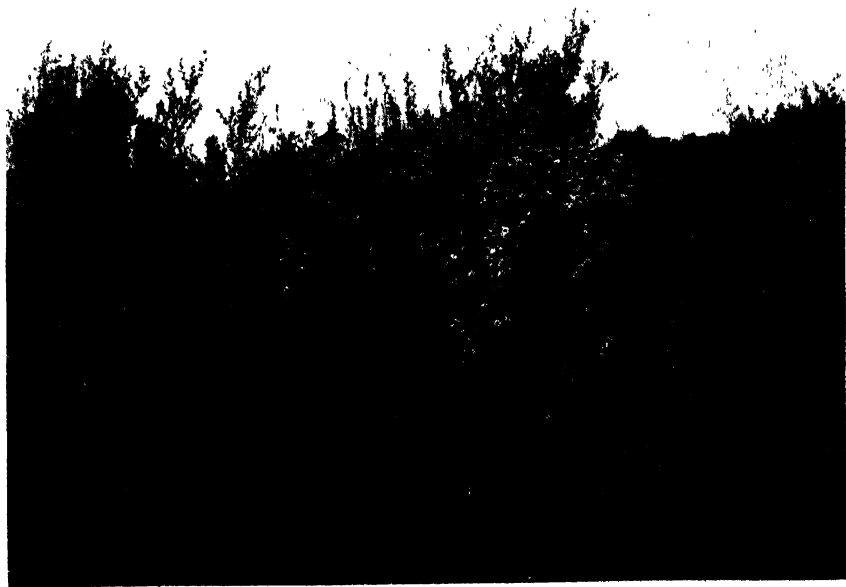
2. COASTAL DYSOXYLUM SPECTABILE FOREST, STEPHENS ISLAND, COOK STRAIT

The forest floor is free of undergrowth, probably partially damaged by cattle. The *Dysoxylum* has characteristically twisted trunks and above-ground roots. The slender trunks are *Piper excelsum*. (Photograph by L. Cockayne, courtesy New York Botanical Garden.)



1. TREE FERN, SHORE OF LAKE ROTO-ITI, NORTH ISLAND

Large tree ferns of many kinds are denizens of the forests and cut-over lands, and often of the roadside



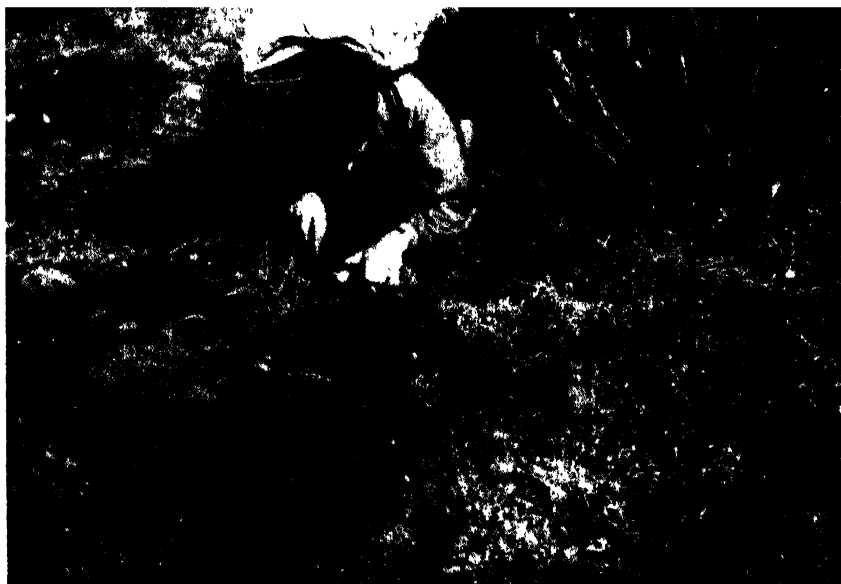
2. MANUKA (*LEPTOSPERMUM SCOPARIUM*), EAST COAST SOUTH ISLAND

This abundant association clothes vast open lands from sea coast and swamps to mountain sides with an almost impenetrable thicket. (Photograph by L. Cockayne, courtesy New York Botanical Garden.)



WILD IRISHMAN (*DISCARIA TOUMATOU*), A DIVARICATING SHRUB, DRY EAST COAST OF SOUTH ISLAND

This characteristic growth habit is found in many New Zealand shrubs. See also plate 7, figure 1 (Photograph by L. Cockayne, courtesy New York Botanical Garden.)



2. COLLECTING *DONATIA NOVAE-ZELANDIAE* IN AN ALPINE BOG, MAUNGATUA RANGE, OTAGO PROVINCE, SOUTH ISLAND

This dense flat mat is so solid that footprints hardly show. Other species of this genus occur only in Tasmania and southern South America. (Photograph by E. H. Walker.)



1. HOOKER VALLEY BELOW THE HERMITAGE EAST SIDE OF SOUTHERN ALPS, CANTERBURY PROVINCE, SOUTH ISLAND

A debris-choked glacial valley with braided streams thick with glacial grindings is gradually invaded by wild Irishman shrubs (*Discaria tomentosa*) and alluvial fans of weathered rock. (Photograph by E. G. Holt, U. S. Soil Conservation Service.)



2. MOUNTS COOK AND TASMAN WITH THE FOX GLACIER, WESTLAND PROVINCE, SOUTH ISLAND

Rain clouds, rising against the range, drench the rain forests on the lower slopes and cover the higher peaks with deep snow, whence flow the glaciers. (Photograph by E. G. Holt, U. S. Soil Conservation Service.)



1. EROSION AND ITS CAUSE NEAR WAIHO DOWNS, SOUTH OF TIMARU, CANTERBURY PROVINCE, SOUTH ISLAND

When sheep overgraze the grass and cut the turf, erosion occurs. Fencing out the sheep (left) allows the vegetation to help control erosion. (Photograph by E. G. Holt, U. S. Soil Conservation Service.)



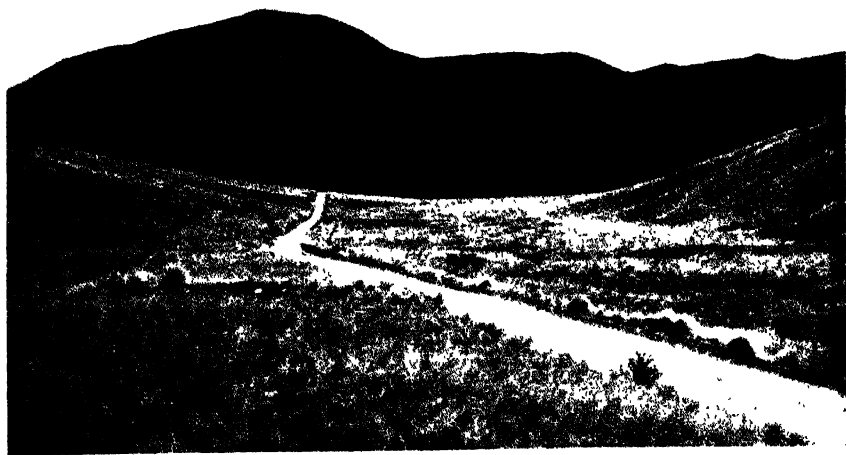
2. AN OVERGRAZED HILL IN TUSOCK-GRASS COUNTRY, LINDA PASS, OTAGO PROVINCE, SOUTH ISLAND

Soil, bared by overgrazing between the tussocks, is covered with pale green scabweed (*Raoultia lutescens*) which in turn nurses tussock-grass seedlings. (Photograph by E. H. Walker.)



1 PASTURE LAND, HERE GAUNGA PLAIN HAWKES BAY, NORTH ISLAND

Rich pastures of introduced grasses are often separated by hedges and windbreaks of lombardy poplars and Monterey pine or cypress. Turnips or swedes are grown for winter feed. (Photograph by E. G. Holt, U. S. Soil Conservation Service.)



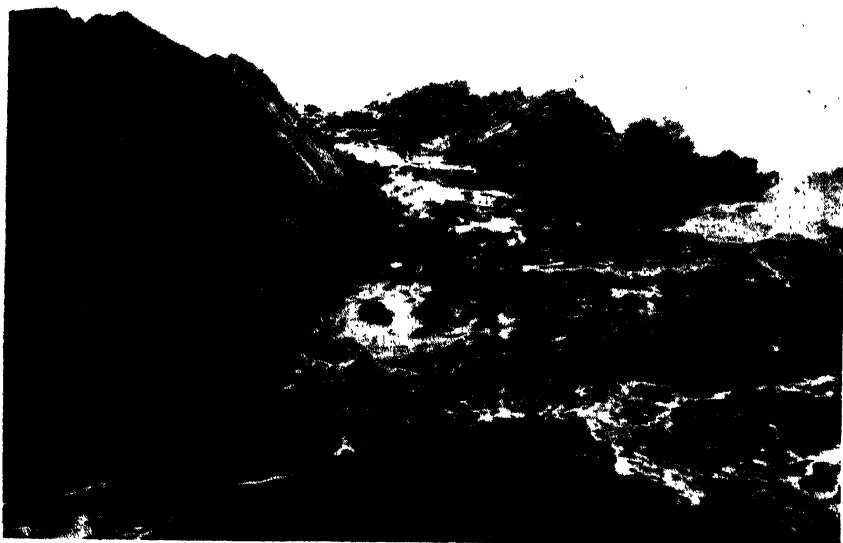
2 BREAST HILL STATION IN THE LOW TUSsock LAND OF CANTERBURY PROVINCE, SOUTH ISLAND

Sheep stations (ranches) are protected by windbreaks of planted pine. The roadside vegetation is little grazed and more luxuriant. (Photograph by E. G. Holt, U. S. Soil Conservation Service.)



1. VEGETABLE SHEEP (*RAOULIA MAMMILLARIA*) AT 4,700 FEET ON MOUNT TORLESE, CANTERBURY PROVINCE, SOUTH ISLAND

The "pimples" on the near end are flowers. This weird plant is characteristic of open shingle slopes in the dry area. (Photograph by L. Cockayne, courtesy New York Botanical Garden.)



2. BULL KELP (*DURVILLEA ANTARCTICA*) ON ROCKS AT LOW TIDE, DOG ISLAND, FOVEAUX STRAIT

This flat-bladed leathery kelp grows abundantly on wave-lashed rocky shores. (Photograph by L. Cockayne, courtesy New York Botanical Garden.)

The kauri forest is the best known of the rain-forest associations, this being due to the noble as well as the highly commercial attributes of its prominent component, the kauri tree itself.⁶ (See pl. 2, fig. 1.) Originally almost all of North Island north of the 38th parallel, which crosses the island about the base of the Bay of Plenty, was a vast kauri forest. The title of a recent booklet, "The Waipoua Forest: the Last Virgin Kauri Forest of New Zealand" (21), shows its present state. The Waipoua State Forest or the Waipoua Forest Reserve in North Auckland contains about 40,000 acres, of which about 27,600 acres is actually forested. Perhaps the Trounson Kauri Park with only about 975 acres is too small to consider, but nevertheless it contains a primeval kauri stand of limited extent, donated by its lumberman namesake to the State for a preserve. Because of its small size and the natural degeneration from its exposed margin, its longevity as a primeval forest may be limited. The kauri forest formation is composed of many other tree species besides *Agathis australis*, as well as characteristic shrubs and ferns, including huge tree ferns, and a few herbaceous plants. Among the many climbers is the kie-kie or climbing pandanus (*Freycinetia banksii*) (pl. 2, fig. 2), the only New Zealand member of this tropical family, Pandanaceae. This forest varies according to the presence or absence of the actually dominant trees, especially of *Beilschmeidia tarairi* in the northern and *B. tawa* in the southern part of its range. Various studies have been made of this forest from different points of view, but probably Cockayne's (5) and McGregor's (21) are of greatest interest to the botanist.

Impermanence seems to be woven into the fabric as well as the history of the kauri forest. Cockayne (6) has stated that the kauri is always in a state of progression or retrogression. Seedling kauris cannot normally reach maturity within the kauri forest itself, but must grow up where there is more light, for this forest is predominantly dark, gloomy, dense, and almost impenetrable. Seedlings grow well, however, in the shade of the manuka or in accidental clearings and along roadsides cut through the forest. By some it is thought that the kauri forest will in time cease to exist unless man takes a hand to perpetuate it. But the Maori people first came only 800 years ago and the white man less than 150, and there were kauri forests many centuries earlier. There is in New Zealand now a lively controversy over the preservation of the Waipoua State Forest. Shall it remain as it now stands, or be reduced in size? Shall it be left wholly untouched, or is it to be altered within by forest management? Shall it furnish timber to commercial exploiters or forest managers, or be a recreation ground and memorial of the past to the

⁶ Actually the kauri tree is not dominant, as it grows singly or in clusters. Kauri forests are so named because of the prominence and commercial value of the kauri. The broad-leaved dicotylous species are actually dominant.

public, or an untouched natural research laboratory to the scientist? Able protagonists have arisen to fight for its preservation from commercial exploitation (21).

The many complexities and variations in the mixed dicotylous-taxad forest can only be suggested here. Such a forest may be a rimu forest with the "red pine" (*Dacrydium cupressinum*) dominant, a totara forest with *Podocarpus totara* dominant, or a tawa forest with the principal trees *Beilschmeidia tairare* or *B. tawa* of the dicotyledonous family Lauraceae, though usually with *Podocarpus* or *Dacrydium* also present. These forest types intergrade and vary extensively, so it is often difficult to determine just what kind of tropical forest one finds himself in.

The parallels of 38° and 42° south latitude are significant as the southern limits of quite a number of species and the northern limits of others. As noted above, the kauri ceases at about 38° south. Some of the 100 or so others which drop out at this point are the toru (*Persoonia toru*—Proteaceae), the white-flowered tawari (*Ixerba brexioides*—Saxifragaceae), the climbing fern (*Lygodium articulatum*), and the trailing fuchsia (*Fuchsia procumbens*—Onagraceae). The 42d parallel, where many other species drop out, cuts off the northern end of South Island. The fact that this unnatural boundary does not coincide with Cook Strait between North and South Islands suggests the geologically recent separation of the islands.

In addition, certain plant forms drop out at various points. For example, the numerous epiphytes of the mixed rain forests of the west coast of the South Island are conspicuously lacking in the rain forests of Banks Peninsula, the vicinity of Dunedin in Otago, Southland, and Stewart Island. The composition of these mixed rain forests changes also with variations in the atmospheric humidity, the soil moisture and composition, the altitude, and perhaps the geological and biological history. The dicotylous-taxad association of the better-drained land gives way to a much more pure association of "white pine," kahikatea (*Podocarpus dacrydioides*) in poorly drained or swampy lands, as formerly existed in some prominence in Canterbury on the dry side of South Island. Here the deleterious effect of the drier air, inimical to the best growth of most rain-forest trees, was compensated for by the greater and more steadily available ground water. The swamp-land forests of Stewart Island are dominated by another tree, *Dacrydium intermedia*. Altitude, or the changed environmental factors that go along with changes in altitude, also cause changes in this mixed association. As it rises higher on the mountains it is gradually replaced by southern-beech forests. On Mount Egmont, however, they give way to another altitudinal forest association composed of kamahi (*Weinmannia racemosa*—Cunoniaceae) and the New Zealand

cedar (*Libocedrus bidwillii*—Pinaceae). These numerous changes are dealt with by Cockayne (7) and in many special accounts and reports of the vegetation of certain localities.

The southern-beech forest extends intermittently, essentially from the central plateau of North Island to Southland in South Island (pl. 1, fig. 1), but is lacking in a stretch of Westland and does not occur on Stewart Island. In former times it was often called birch, but this erroneous designation is seldom used today. These forests are usually composed of just one species of *Nothofagus*, or at most two. The species change rather strikingly with changes in altitude. The forester is not content with the taxonomist's five species of this genus, but is able to recognize in this complex a great many more entities or variations, most of them more or less significant to him in dealing with this economically important forest association. It is now the most important native timber tree, since the kauri is practically gone as a source of commercial timber. Hence, the foresters are working out ways of conserving, extending, and using the beech forests of South Island. Soil conservationists are interested in *Nothofagus* forests, for these can prevent erosion on mountain slopes, if man would only let them alone or aid Nature to restore them. But man's ax and fire have laid waste large tracts of mountain slopes. And now another danger threatens the beech forests. The deer which man introduced for sport, or their progeny, are busy browsing and trampling the young beech seedling so that in places the undergrowth of young seedlings has disappeared. The solution for the regeneration of these forests seems to be the extermination of the deer, or at least the keeping of the population under control at a much lower level than it is today. Indeed, the problems of future forests involve many factors in this fascinating country.

THE FLORA, OR THE PLANT SPECIES COMPRISING THE VEGETATION

Many species of New Zealand plants are possibly unimportant in considering the structure, origin, and distribution of the vegetation or plant associations. They are, however, extremely important in relation to the flora as a whole and the understanding of its origins, affinities, and distribution. There are too many interesting species to deal with them at all thoroughly here, but some aspects of the flora can be reviewed. The marine and fresh-water algae (pl. 10, fig. 2), and the other lower cryptogams must be omitted, but with full recognition of their great interest and importance. Although New Zealand is famous as a pteridologist's paradise, the ferns, too, must be largely ignored. (See pl. 5, fig. 1.)

One's first impulse in looking at the New Zealand flora is to divide it into two categories, the native plants and those introduced by man.

Each seems a separate unit and the visitor with limited time tends to pass over the introductions. There are, however, so many interesting and important botanical features in both floras that neither should be omitted.

THE NATIVE FLORA

The indigenous flora of New Zealand is among the most distinctive of the world's floras. It is not especially rich in number of species, Cheeseman's Manual (4) listing only 1,763 species, but it contains a wealth of fascinating members, mostly belonging to genera and families unfamiliar to the traveler from northern lands. About 78 percent of the indigenous species of ferns and seed plants are endemics, that is, are not found anywhere else in the world. This becomes 88 percent if the ferns and monocotyledonous plants are excluded, and even higher if only the forest species are considered. Forty genera are found only in New Zealand. Among the more conspicuous or significant are the lacewood (*Hoheria*—Malvaceae), one of the few natives which has conspicuous and ornamental flowers and is deciduous, and two composite genera, *Haastia* and *Raoulia*, which form the "vegetable sheep" (pl. 3, fig. 2, and pl. 10, fig. 1), for which New Zealand is noted. The reasons for the occurrence of these species and genera only in New Zealand are mostly obscure, and leave much yet to learn. They may have evolved here or they may have had a widespread distribution and have died out elsewhere. It cannot readily be determined that these represent a flora which developed in New Zealand, rather than one that came from some other part of the world in remote geological times, but the evidence is that such flora did evolve here. It is called the palaeozelandic flora and certain genera are tentatively assumed to belong to it. They include the three strictly endemic genera just mentioned, besides others now found elsewhere but which probably originated here. Among them are the distinctive New Zealand pine (*Dacrydium*) in the Taxaceae, the New Zealand broom (*Carmichaelia*—Leguminosae), the widespread shrub *Coprosma* (Rubiaceae) of distinctive divaricating habit and many species, and the woody genus *Hebe* (Scrophulariaceae), which is often combined with the widespread genus *Veronica* with mostly herbaceous species.

The majority of the nonendemic species and genera are found also in Australia. One might suppose this indicated a relation between the floras of the two regions, but too much emphasis should not be given to this numerical superiority of the Australian element. It is just as important in considering this relationship that certain prominent Australian groups do not occur in New Zealand. Thus in these islands there are no native eucalypts (*Eucalyptus*—Myrtaceae), bottle-brushes (*Callistemon*—Myrtaceae), *Melaleuca* (Myrtaceae), wattles (*Acacia*—Leguminosae), and other significant genera, especially

legumes, and only two genera, *Persoonia* and *Knightia*, of the conspicuously Australian family Proteaceae. Few of the Australian elements are familiar to travelers from the North Temperate Zone. One that a visitor to the New Zealand forest will soon meet, however, is the supplejack (*Rhipogonium scandens*—Liliaceae), a conspicuous vine which hangs from the tops of the trees. Another is the genus *Celmisia* (Compositae), whose many New Zealand species are among the chief ornamentals in the montane and alpine vegetation (pl. 3, fig. 2).

Besides the Australian element there are indigenous species and genera, found also in the Malay Archipelago and the Pacific region, but they are fewer than the Australian ones. The kauri is of this group, for certain other species of *Agathis* grow in Australia, New Caledonia, Fiji, and elsewhere. The climbing pandanus (*Freycinetia*) (pl. 2, fig. 2) and the only New Zealand palm (*Rhopalostylis*) (pl. 3, fig. 1) belong to definitely Malayan-Pacific groups.

The third group of indigenous but not endemic elements is the subantarctic, most conspicuously represented by the southern-beech (*Nothofagus*), already mentioned. There are a good many genera and some species in this group with distribution around the southern Pacific, some with extensions into more northern regions. They are of much interest to plant geographers in understanding the past geological history of this whole southern region.

Finally, there are New Zealand plants with a world-wide distribution constituting the cosmopolitan element. An example is the widespread bracken, *Pteridium aquilinum*, the New Zealand variety of which, var. *esculentum*, grows to such great size, as already noted. Most of these cosmopolitan species are seashore or littoral plants.

These floristic elements and their origin have been discussed by various authors, including Wallace (27) and Cockayne (7). The subantarctic flora has been most thoroughly dealt with by Hooker in his introduction to the *Flora Antarctica* (14) and by Skottsberg (24).

BOTANICAL DISTRICTS

More significant to the traveler than the origin of the indigenous elements of the flora, is the distribution of the species within the islands. This has already been mentioned in connection with the various plant formations and their occurrence, but consideration of the species rather than the formations brings out more clearly the botanical divisions of New Zealand. Through a lifetime of study of the vegetation and plants of this area, Cockayne (7) has divided the country, exclusive of the outlying islands, into 16 more or less distinct botanical districts. There is, of course, some disagreement with these divisions and other workers will alter them when new studies and interpretations are made, as Cockayne himself predicted. The districts are

shown on the accompanying map, figure 2.⁷ The following characterizations are largely derived from Cockayne's publications and the writer's personal observations. Only a few of the many outstanding species are here mentioned.

Northwest of North Cape lies the seldom-visited **Three Kings District** composed of a small group of islands with this name. Their flora includes 10 species of plants not found elsewhere in New Zealand, 6 of which are obviously related to New Zealand species, 3 have relatives only toward the north, and 1, a species of *Chloris* (Gramineae), is of almost cosmopolitan affinity, although not found elsewhere in New Zealand. The impoverishment of this flora by introduced grazing animals, especially goats, and its recovery after these were removed is an interesting study with significant implications for other likewise devastated areas. These Islands have recently been treated botanically by Oliver (23) and Baylis (3).

In the **North and South Auckland Districts** there are more than 100 species of plants which do not occur farther south, or extend only a short distance beyond the southern limit at approximately the 38th parallel. The kauri tree has already been mentioned in this connection. The taraire (*Beilschmeidia taraire*), usually the dominant tree in the kauri forest, does not go farther south as does the other important kauri associate, the tawa (*B. tawa*). Several ferns are found only here, as well as the parasite *Cassytha paniculata* (Lauraceae), which resembles, but is no relative of, the dodder (*Cuscuta*) of wide distribution. This parasite genus occurs in the Pacific area, Australia, and the gumlands of northern North Auckland. It is a hazard to walking wherever it grows as it binds together the manuka and other shrubs by dull green resistant cords. An interesting phenomenon is the occurrence on the small islands adjacent to these districts of species or varieties similar to those on the main island, but with larger leaves, flowers, or fruits, among other differing characters. These islands are difficult to reach, but one can often find these distinct plants growing in private gardens, nurseries, and parks where enthusiastic New Zealand botanists grow them. Several species have their northern limit in the South Auckland district, one being the silver beech (*Nothofagus menziesii*). Although there are no natural grasslands in this area, there are extensive man-made pastures with certain distinct plant species, mostly grasses. The mild climate makes it possible to grow certain citrus fruits and other subtropical crops with success.

⁷ After this map was prepared Cockayne and Allan (8) proposed an additional district, the Sounds-Nelson Botanical District, comprising the South Island portion of the Ruahine-Cook District, which formerly straddled the Cook Strait. This district was recognized in Cockayne's larger work (7), which is followed in this survey, but which does not have a map suitable for reproduction here.

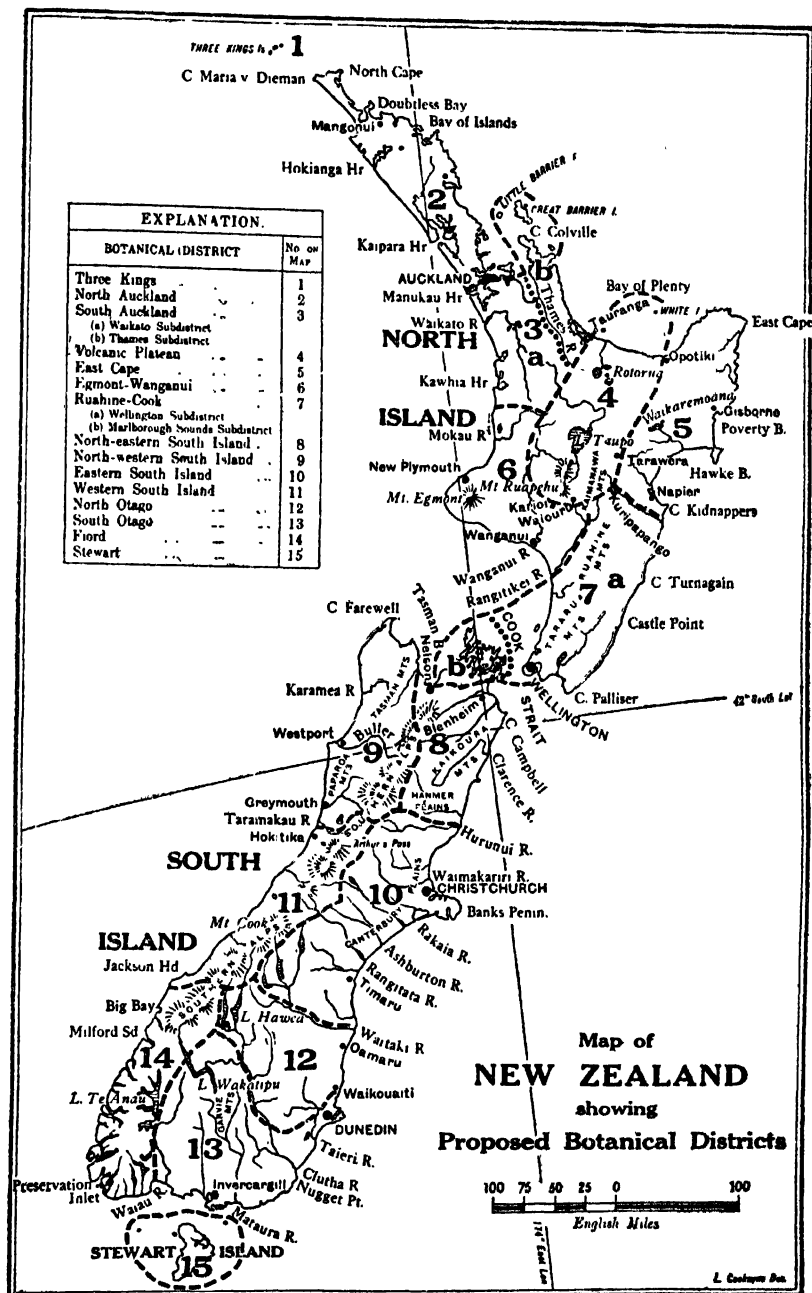


FIGURE 2.—The botanical districts of New Zealand, according to L. Cockayne (6).

The first natural or tussock grasslands as one progresses southward are found in the **Volcanic Plateau District**. Here one begins to see certain characteristic subalpine shrub formations, especially of monoao (*Dracophyllum subulatum*—Epacridaceae). The volcanic mountains, three of which are still active, raise their summits far above timber line and support a fascinating alpine flora.

The northern tip of the **East Cape Botanical District** is within the northern plant zone marked off by the 38th parallel, so contains some northern plants. The southern part in the Hawkes Bay region is drier, hence it has certain agricultural possibilities not found elsewhere. Maize or Indian corn (*Zea mays*—Gramineae) is grown for its grain, but elsewhere mostly for fodder.

To the botanist Mount Egmont is probably the first attraction of the **Egmont-Wanganui District** in the southwest portion of North Island. However, its high mountain flora is less rich than is that in the mountains of the central plateau, which are visible in good weather from Egmont's higher slopes. The zones of vegetation on this isolated volcanic cone, however, are very vivid. There are few plants endemic to this district and the southern-beech forests are absent. A forest of tawa (*Beilschmeidia tawa*) probably originally covered most of the lower land, of which the Wanganui plain is the most significant, but the area is now almost entirely converted into agricultural land. The moist, mild climate has led here to the extensive development of dairying, a most thriving enterprise based entirely on artificial pastures.

The **Ruahine-Cook District** occupies the southeastern segment of North Island, with Wellington as its principal city. It is divided by the Ruahine and Tararua Mountains into two parts, the eastern or protected side having a drier climate. The west side is influenced by the winds and storms, so characteristic of Cook Strait, and sand dunes and wind-shaped trees and shrubs are common. There are remnants of various forest types in the lowlands, and southern-beech forests extend up to timber line in the mountains. Most of the North Island alpine species and formations are found on the higher slopes. (See pl. 3, fig. 2.) Among the lowland forest types is one composed primarily of the kohekohe (*Dysoxylum spectabile*), the only member of the Meliaceae in New Zealand. (See pl. 4, fig. 2.) It is a relatively open forest with dense shade, many lianas, and few undershrubs. This tree bears flowers and fruits on the larger branches and trunk, a characteristic fairly common in the Tropics and subtropics. The occurrence of mixed dicotylous-taxad forests and southern-beech forests at the same or adjacent elevations, but on slopes with different exposures, gives one an opportunity to see vividly the contrasts between these two types of forest. Certain mountain plants of South Island may be found on the exposed coast of Cook Strait at sea level.

The **Sounds-Nelson District** has remnants of forests almost identical with those of the preceding district, of which it has been considered only a part (6, 8). Cook Strait is less of a natural boundary than the parallel of 42° S. which crosses South Island below this Sounds-Nelson District. The striking features of this district are the beautiful long, rugged sounds in the north and scattered, lofty mountains toward the south. The climate is one of the best in New Zealand, and agriculture of a more mixed nature than in most parts is well developed in the valleys and lowlands, especially about the principal city, Nelson. From this progressive center one can readily reach the diverse botanical associations and seek the unusually large number of endemics. The famous Mineral Belt crosses this district with its vivid exhibition of the effect of an excess of magnesium in the soil on plant growth. Here at a nonalpine elevation are alpine and other plants with a dwarf or dwarfed habit growing on the mineral or serpentine belt only a few yards from rich taxad and southern-beech forests growing on nonmineral soil. One of the principal interests of the Cawthron Institute in Nelson is in mineral deficiencies in agricultural soils. Hops, tobacco, and fruits are among the crops grown in this district.

The **Northwestern District** is a mountainous area with some broad valleys. The rainfall is heavier, especially in the southern part, than it is farther east and agriculture is less well developed. It contains about 30 endemic species including *Pittosporum* (Pittosporaceae), a species of the epiphytic tree genus *Metrosideros* (Myrtaceae) (pl. 2, fig. 2), a native broom (*Carmichaelia fieldii*—Leguminosae), gentians, forget-me-nots, and species of the variable woody genus *Hebe* (Scrophulariaceae). This genus is so closely related to *Veronica* with only herbaceous species that they are often combined under the latter name. Here one finds certain wet areas called *pakihis*. They would be considered bogs if they contained more peat. They are underlain by an impervious soil of "iron pan" and stones, causing water to collect on the surface. Characteristic plants are sedges of the genus *Cladium*, the bog umbrella-fern (*Gleichenia umbellata*) not found between here and North Auckland, and a gentian. Here also occurs *Epacris pauciflora* of the family Epacridaceae, which in this part of the world furnishes the heaths, as the closely related Ericaceae do in the Northern Hemisphere. There are, furthermore, a few orchids, sundews (*Drosera*—Droseraceae), an endemic species of an endemic genus, *Siphonidium longiflorum* (Scrophulariaceae), and a few other plants, as well as that amazingly adaptable shrub, manuka.

In the **Northeastern District** there are very few forests, except in the Seaward Kaikouras, the coastal one of several mountain ranges which dominate this essentially dry area, characterized by low tussock grasslands. Here occurs one of the two almost desert regions of

New Zealand already mentioned (p. 320). The many endemic species, often of very restricted range, as is characteristic of those of South Island, are largely denizens of open rocks and high, barren, stony fields called fell-fields. Here, as throughout the drier mountains of New Zealand, occur extensive "shingle-slips" on dry mountainsides where weathering has broken the greywacke rock into deep layers of loose shingle. (See pl. 7, fig. 1.) On this formation grow certain distinctive shingle-slip plants, mostly isolated or in small colonies and specially adapted to these precarious life conditions. One of those most distinctive cushion growths known in New Zealand as vegetable sheep is characteristic of this Northeastern District, *Haastia pulvinaris* (Compositae). It also occurs in the adjacent districts to the west and northwest. Other vegetable sheep are mostly in another composite genus, *Raoulia*, a widespread and variable New Zealand group of about 22 species of a characteristic, extremely dense growth form, especially adapted to dry areas.

The **Western District** is an area of dense temperate rain forest of taxads and associated dicotyledonous trees on the western side of the Southern Alps. There is no beech forest except high up on the mountains (this perhaps properly belonging to the eastern province), and at the northern and southern ends of the district. The rainfall on the coast and mountain slopes and the snowfall in the high mountains are excessive. The traveler here feels he is in a pioneer atmosphere where man has only begun to despoil nature, except perhaps toward the northern end. Agriculture is limited by the extent of the forests, the rainfall, and the narrow coastal strip. Sheep are replaced by cattle which thrive better under such humid conditions. The great attractions to botanists as well as others are the Franz Joseph and Fox Glaciers (pl. 7, fig. 2), which extend far down from the great snow fields above through deep gorges. Their tips are just under 700 feet above sea level, far down among the forests. Here is the only place where one can photograph a glacier in a framework of tree ferns. There are a few endemics in this wet district.

Over the divide on the opposite side of the Southern Alps is the **Eastern District**, almost the antithesis of the western. Here are extensive tussock grasslands instead of forests, and low instead of high rainfall, dry instead of almost saturated atmosphere, and well-developed agriculture, with wheatfields instead of stump-filled clearings recently cut from the "bush." The prosperous city of Christchurch is the center from which to become acquainted with this area. The climate may be called semicontinental. Temperatures range higher and lower than in most other parts of New Zealand except Otago Province, and the precipitation varies. There is much discussion as to the original extent of the grasslands (pl. 9, fig. 2) and the forests, but the latter, undoubtedly never very extensive, are now

much less so. Remnants occur in the Canterbury Plain of the swamp forest or kahikatea, composed of *Podocarpus dacrydioides* (see p. 328). In the high mountains are fell-fields, amazing shingle-slips, and other alpine formations, each with characteristic plants. Mount Torlesse, with its vegetable sheep (*Raoulia eximia* and *R. mammillaria*) (pl. 10, fig. 1), and other characteristic alpine plants, is a well-known mountain rather easily reached from Christchurch. The Banks Peninsula, with mountains of volcanic origin which can wrest moisture from the eastern winds, constitutes a subprovince. It, too, has certain endemic plants and formerly had dicotylous-taxad forests, now largely gone to make way for prosperous dairy farming.

Reference has already been made (p. 320) to the desert conditions in Central Otago, which is the outstanding characteristic of the **North Otago District**. This is the hottest and driest, as well as the coldest, part of New Zealand. It owes this distinction to the protection from the rain-laden westerly winds and the failure of the southwest winds, which bathe the area to the south, to reach this district. Its desert conditions have been aggravated by overgrazing (pl. 8), burning, and the nibbling of an amazingly dense rabbit population. Irrigation in river valleys makes possible the growing of certain fruits and alfalfa. There are a few endemic plants, mostly xerophytes, some of them grazed almost to extinction. The weed population is perhaps more conspicuous than elsewhere in New Zealand. Forests are practically absent.

The least-interfered-with and the botanically least-known part of New Zealand is the **Fiord District**, an area of difficult access because of the meagerness of means of transportation and of population. Its boundaries are rather vague, especially the separation from the South Otago District. Forests of taxads and of southern-beech stretch from seacoast to timber line. Almost the only open land is the tussock grassland in the alpine zone between the tree and the snow lines. The distinctive or near-endemic plants are largely low ground plants or shrubs, most of which occur also in the districts toward the east. Here was recently found, in an isolated valley, the supposedly extinct flightless bird, the takahe (*Notornis mantelli*), one of the group of rails. Within 3 weeks of this discovery a large area was declared by the New Zealand Government to be a reserve where only those with special permits could go. Such rapid action bodes well for future conservation. One wonders what rare plants may also some day be found in this district of superb wild scenery. Those who have been in this district so far have found it of rather more zoological than botanical interest.

In the **South Otago District**, which includes southern Otago and most of Southland Provinces, the moisture comes largely from the wet southwest winds, which leave snow on the high mountains in the

west. Elsewhere the land is also mountainous with fertile plains between. From Dunedin one can readily reach mountains with many specially interesting plant formations and some forests. (See pl. 6, fig. 2.) Farther south are the eastward extensions of the beech forests of Fiordland, which so far cannot be set off by any definite line. Originally in the east were dicotylous-taxad forests differing from those farther north in their fewer species, but the forests in this area have suffered much from the ax of the settlers, who are still pushing steadily westward. The tussock grasslands at lower elevations are extensive, as well as the alpine formations high on the mountains. There are only a few endemic species in this district. Agriculture is well developed, some of the most prosperous farms in New Zealand being in the vicinity of Invercargill in the south.

The most unaltered part of New Zealand is the **Stewart Island District**, unless it may have to contest this honor with the Fiord District. It is for the most part heavily forested with dicotylous-taxed forests, which are very similar to those of southern South Island, just across stormy Foveaux Strait. Remarkable swamp or kahikatea forests occur here, dominated by *Dacrydium intermedium* and distinguished by very numerous huge moss and livewort cushions on the forest floor. There are no beech forests on Stewart Island, and several other trees and shrubs that one would expect to be here are wanting. Altogether about 500 species of plants are to be found with about 20 endemics. Several species are found elsewhere only on the subantarctic islands to the south or are closely related to plants of that region. Stewart Island has an abundant rainfall, high winds, and moderate temperatures, frost and snow being very rare except on the highest mountains, none of which are over 3,000 feet high. As there are no roads except close about the only settlement, Oban, on Half-moon Bay, travel is very difficult. The interior is best reached by rough trails, usually called "tracks" in New Zealand, from nearby points on the coast to which one must go in hired fishing boats. A prominent feature is the characteristic coastal high-shrub formation, often of the composite genera *Senecio* and *Olearia* or tree-daisies, and treelike species of *Dracophyllum* (Epacridaceae), at the bases of which penguins nest. Alpine species are frequently found here at seal level.

Much importance is attached to the study of the subantarctic islands farther south, and they have been visited a number of times by specialists. It is not, however, feasible to discuss them here.

SOME PECULIARITIES OF NATIVE NEW ZEALAND PLANTS

It is impossible in a brief survey such as this to take up even the most interesting plants. There are, however, a few outstanding characteristics or peculiarities of the plants of this flora which will

be of interest. In the first place, there are few annual or biennial plants in the native flora. Then it is striking that many genera, which in other parts of the world have mostly herbaceous species, here have only or mostly shrubby ones. Why the long-isolated New Zealand flora should have developed a flora without annuals and biennials and with this emphasis on woody plants is somewhat puzzling. There were no grazing animals in New Zealand until the white man came, except possibly the large extinct flightless bird, the moa. Hence, the course of evolution may have been slightly different from what it was in other countries where grazing animals could have influenced the development of the flora.

A puzzling characteristic of about 200 species in 32 different families is the development of different types of foliage and growth habits at successive stages in an individual plant's life. In its youth, which may extend from a month to 50 years, a plant may have a "juvenile foliage," and then develop a strikingly different "adult foliage." These may be so different that one finds it difficult not to doubt the veracity of the local botanists who point out that these different forms of foliage really occur on the same plant and that they do not represent different species. Furthermore, many of these plants in one stage are adapted to one habitat and in the other are better fitted to live in a different environment. Most of these species are endemics, so the phenomenon seems in some way related to the evolution of the New Zealand flora. Are these changes related to past changes in the climate of New Zealand, and are the plants now reflecting their evolution in the stages of development through which the individual plant passes? The phenomenon is a very puzzling one. It is by no means confined to New Zealand, but is more strikingly evident here than in other parts of the world. At any rate this feature has advantages to the plant propagator, for sometimes in cultivation it happens that the "juvenile" stage is more susceptible to an insect or fungus attack than is the "adult" stage. In that case the grower can vegetatively propagate from "adult" plants, thus entirely eliminating the susceptible stage in the development of his plants, unless the adults so grown take a notion to revert to the juvenile habit of growth. Often change to another stage can be induced by altering the growing conditions of plants under cultivation.

Another disconcerting phenomenon to the student of species of the taxonomist is the extreme variation of form that may be found within a genus. A genus may have species which are diminutive in size and others that are huge trees. The taxad *Dacrydium* is an example. This phenomenon occurs in other countries also but it seems to be outstanding here. Great variation within certain species is also very disconcerting, as is the running together of the species in many genera such as *Coprosma* (Rubiaceae). Hybrid swarms are common and

have been given much consideration, over 500 hybrids having been recognized in the New Zealand flora. Thus the taxonomist is often hard put to give a plant a proper name and to define the limits of species. Reference has already been made (p. 324) to the divaricating habit of growth. (See pl. 6, fig. 1.) Indeed, New Zealand has so many engrossing botanical phenomena that the great interest in plants on the part of so many people is not surprising. Perhaps the characterization of the country as a botanical paradise is not an exaggeration.

THE INTRODUCED FLORA

The vividness of the conflict between the introduced and the native flora in New Zealand makes consideration of the exotic plants more worthwhile in this than in many countries. We can study the history of this conflict here more easily than anywhere else in the world for several reasons. In the first place, the geographical isolation of New Zealand has reduced the number of ways plants can come in, thus enabling us more easily to scrutinize these channels. Secondly, there are certain rather definite records of "pre-pakeha" introductions in the legends of the Maori peoples. Finally, the records of plant and animal introductions since the arrival of Captain Cook are fairly complete, and the existing gaps do not materially vitiate the conclusions that may be drawn from these data.

It appears on the surface that the native flora is doomed to disappear under the impact of the more vigorous invaders. But more thorough observations have led to the conclusion that the strength in the newcomers lies in the aid they have gained from man's activities in changing the environment to their advantage and to the disadvantage of the native species. Where competition occurs unaided by man, the indigenous species are able to maintain themselves and win supremacy. With a growing consciousness of the need for conservation in New Zealand, late though it may be, the threat of extinction of the native flora will disappear. But it will be a long struggle to overcome the great losses already suffered here, as in so many other parts of the world, through man's past failure or unwillingness to see the consequences of his acts and to restrain his desire for immediate returns to himself, in the interests of future generations.

Most Maori legends of the bringing of food plants to New Zealand are plausible explanations of the presence of certain species. Among these are the hue gourd (*Lagenaria vulgaris*—Cucurbitaceae), the sweetpotato or kumara (*Ipomoea batatas*—Convolvulaceae), the taro (*Colocasia esculenta* var. *antiquorum* or *C. antiquorum*—Araceae), and the ti tree (*Cordyline terminalis*—Liliaceae). Sometimes, however, these legends do not fit the observable scientific facts. For ex-

ample, legend says that the tree called karaka (*Corynocarpus laevigata*—Coriariaceae) was brought in a canoe about 500 years ago, obviously from Polynesia. But this species is not known in Polynesia or anywhere else outside of New Zealand except in the Kermadec Islands. Possibly it was brought from that group. Another species occurs in the New Hebrides and one in New Caledonia. These Maori introductions do not seem to have influenced the native vegetation. These people did not greatly alter the environment in favor of their introductions, and even when they did do so they usually soon abandoned the fields and let the native flora take over again.

The first definite record of introductions are those mentioned in the account of Captain Cook's second voyage to New Zealand in 1773. He brought animals to release, especially goats, and plants to sow, because on his first visit he was impressed by the shortage of food plants and animals in the country. He wanted to assure a larger supply for his future expeditions. Thus he planted gardens and encouraged the natives to tend them and to plant more. On later expeditions observations were recorded of the few successes and the more numerous failures of these ventures.

Probably few introductions occurred between Cook's voyages and the first regular settlement, which was at Wellington in 1839. It is recorded, however, that potatoes were actually exported to Australia during this time. Then with the influx of immigrants to New Zealand there came accidental weeds, partly with their rough bedding which was thrown out with other refuse full of European weed seeds. When these settlers gained some leisure from the grinding toil of pioneer life, nostalgic longings for the atmosphere of the lovely English countryside overcame them. They sent for plants to lend color to their new homes, where the native plants were generally so lacking in bright flowers. Here were no social class distinctions to keep the people from enjoying the sports reserved at home for the privileged few. Hence, as New Zealand lacked animals, fish, and game birds suitable for sport, deer, hares, rabbits, and other animals were introduced and released with no thought of the future, except the sport of hunting them. Skylarks were brought to make music for settlers' ears, and pheasants to shoot. Soon "acclimatization societies" were formed to aid in bringing in plants and animals. Enthusiasm rose to great heights. Many introductions, according to the records, failed time after time; others succeeded all too well and became destructive elements in the flora and fauna. The story of the efforts of diverse people and groups the world over to introduce plants and animals and then to control those that prove harmful is always the same. Many well-meaning efforts fail from lack of coordination of interested groups and of scientific understanding of the problems

involved either in selecting introductions or dealing with those that threaten to or have run amuck. G. M. Thomson (26) has vividly summarized this course in New Zealand.

The first important list of introduced plants appeared in J. D. Hooker's Handbook in 1867 (15). The latest is that in Cheeseman's Manual, second edition, 1925 (4), since which time other species have arrived and more are constantly being introduced by both official and private interests. Several publications have been issued to aid in identifying introduced plants, as one by Allan (1). In 1922 G. M. Thomson brought together the scattered information on introduced animals and plants (26). His object in compiling the book was to obtain precise data as a basis for understanding what to expect in the conflict between the introduced and the native flora and fauna, and for drawing up effective future scientifically based control measures. He records over 600 species of plants as truly wild, that is, they reproduce by seed and appear to be permanent denizens of New Zealand. Most of them are of European origin, a few are from Australia, and some from America and Asia.

Although widespread harm has resulted from bringing in certain foreign plants, the economy of the country is founded on imported species of plants and animals. The list of introduced plants includes injurious, potentially harmful, harmless, and both injurious and useful species, depending on circumstances. Reference has already been made to several harmful species. A potentially dangerous species is the prickly pear cactus (*Opuntia* sp.) which in Australia has been so destructive. It was reported in 1840 at Hokitika on the west coast of South Island but has not spread. One wonders what would happen if a frost-resistant species were released in Central Otago. Red clover (*Trifolium pratense*) came early, but had to wait for the introduction of the humblebees to pollinate its flowers before it could set out to cover New Zealand. One accidentally introduced weed, the slender thistle (*Carduus pycnocephalus*), which probably came originally as an impurity in farm seeds, now is an emergency winter feed for sheep in Central Otago. But if the native feed had not been overgrazed, this emergency would not arise. An interesting failure seems to be the Chinese paper mulberry (*Broussonetia papyrifera*) reported by Sir Joseph Banks on the first Cook expedition in 1769. It was obviously a Maori introduction, for cloth was made from its bark fibers, but it is not found in New Zealand now, though it is a common weed in most tropical and subtropical and warm-temperature countries. The common mullein has an advantage not shared by most weeds and cultivated plants in that the introduced rabbits and sheep will not eat it.

Many New Zealand introductions show astonishing vigor, rapid growth, and large size. This is especially striking in the Monterey

pine (*Pinus radiata*). At first this phenomenon caused much alarm lest the native flora should be wiped out. When Darwin's ideas on evolution through natural selection first came to people's attention, much speculation arose in New Zealand as to whether new species and varieties would arise capable of overcoming the native flora. Observations, however, do not show evolution of new entities, nor have the fears of the extermination of native species been realized. Although there have been profound changes in the vegetation, there is no known record of the extinction of any species. If the full record of the New Zealand flora at the time of the white man's first arrival were known, we might, however, be able to record today some extinct species. The record of the existence and distribution of New Zealand plants is by no means complete even today. Local extermination has occurred in many places. For example, the antiscorbutic, *Lepidium oleraceum* (Cruciferae), which Captain Cook found abundant and which supplied his urgent need, is now rare, thanks to the depredations of appreciative sheep. The traveler will see and be shown many examples of formerly common but now rare plant species and the efforts being made to protect them. They usually show maintenance vigor when man's introduced grazing animals, sheep, goats, and rabbits, are eliminated. (See pl. 8, fig. 1, and pl. 9, fig. 2.) But at the same time aggressiveness is not confined to the introduced flora. Often when man has changed the natural habitats, indigenous species have been the invading weeds rather than vigorous exotics. The most notable of these are the manuka (*Leptospermum scoparium*) (pl. 5, fig. 2) and the bracken (*Pteridium aquilinum* var. *esculentum*), already described.

Indeed, the introduced flora is well worth the traveler's attention.

BOTANICAL STUDY AND RESEARCH

Scientific interest in New Zealand plants began with the first explorers. The noted botanists Sir Joseph Banks and Dr. Daniel C. Solander accompanied Capt. James Cook on his first voyage to New Zealand in 1769. Most other expeditions that came here in the early days also made scientific observations and collections. We even owe some scientific knowledge to the early whaling voyages that preceded the settlement of New Zealand. The settlers were for the most part of a class which was alert and inclined to make observations, and many people recorded what they saw and sent collections to the European scientists. Officials and missionaries gleaned rareties from the countryside as they went about on business and mission trips. The nomenclature of New Zealand botany is full of memorials to their work, as *Haastia* (Compositae) for Sir Julius von Haast and *Colensoa* (Campanulaceae) for Rev. William Colenso. Scientists with various

expeditions collected here, but the most noteworthy was Sir Joseph Hooker who wrote various works on the Antarctic and New Zealand, including the first real flora of this future Dominion (14). Naturally, early work was done in England, but gradually scientific works began to appear in New Zealand. The Government fostered scientific work at an early date and the larger part of present-day botanical research is being carried on within the Government. Among the many botanists of New Zealand only two may be mentioned here for lack of space. Names of others are noted in the bibliography and in various works there listed. Leonard Cockayne contributed greatly, not only to the knowledge of ecology and phytogeography in New Zealand, but also to the dissemination of this knowledge among the people by his practice of writing for both the laymen and the scientists. (See especially (6).) T. F. Cheeseman issued the first edition, in 1906, of the now widely used *Manual of the New Zealand Flora*, the second edition having been issued in 1925 (4). It is now being revised again by H. H. Allan.

The principal herbarium collections of plants in New Zealand are deposited in the Auckland Memorial Institute and Museum, the Division of Botany of the Department of Scientific and Industrial Research (everywhere known as the DSIR) of the Government in Wellington, the Dominion Museum in Wellington, and the Canterbury Museum in Christchurch. Botanical research is being promoted very actively, especially by the DSIR. Botany is being taught and research conducted in all the scattered colleges of the University of New Zealand, in Auckland, Wellington, Christchurch, and Dunedin. The agricultural colleges are, of course, doing research in applied botany, as is also the Cawthron Institute in Nelson which is specially concerned with basic agricultural problems.

The extent of this research and teaching is a recognition of the importance of botanical science in the development of the country. Much has been done, but in a real sense the surface has only been scratched. Cockayne's major work on the vegetation is an excellent comprehensive treatment, but the author recognized that it was a preliminary presentation. Cheeseman's excellent flora is subject to improvement, as indeed is every other flora ever published.

One cannot in a survey such as this even touch upon all the facets of the subject. Many important plant formations and fascinating plants have been left for the traveler and the reader to discover. The fields of marine algae and fossil pollens are very lively and promising subjects of research in New Zealand today. Fungi are coming into their own, and bryophytes are by no means neglected; at least the groundwork has been laid. The ferns of New Zealand are famous and much has already been published on them. Nor are the laboratory

and experimental aspects of botany neglected. All are thriving and carrying on the advancement of pure and applied science in New Zealand.

The botanical traveler in New Zealand will soon come to know many amateur and professional botanists. Nearly every community has a local naturalist or two, often with special interest in some limited group of plants, and nearly all much interested in growing native plants in their gardens. The commercial nurseries are in tune with this spirit and have separate sections devoted to natives which can be successfully grown in gardens. The city parks are usually dominated by exotics, but it was most gratifying to hear one superintendent with 3,600 acres of park and public domain in his care, in a city of under 11,000 population, explain his extensive use of native species. The planting of natives versus exotics in reforestation is a lively subject.

Botanical travel in New Zealand is relatively simple and most parts, except the Fiord region of the southwest and Stewart Island beyond the Halfmoon Bay region, can be reached by car, train, bus, or boat plus not too strenuous walking. The diffusion within the population of people sympathetic to botanical travelers makes the experience one never to be forgotten. The common bond of the English language facilitates explanations freely given. The handicap to the visitor of the frequent use of native Maori names is lessened by the unusual familiarity of many people with scientific names, so necessary for clear understanding. Indeed, New Zealand is a botanist's paradise.

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THE ARCHEOLOGICAL IMPORTANCE OF GUATEMALA

BY A. V. KIDDER

*Chairman, Division of Historical Research
Carnegie Institution of Washington*

[With 6 plates]

The high aboriginal cultures of Mesoamerica extended from north-central Mexico well into Nicaragua. Guatemala lies almost exactly in the middle of this great area. Not only is it central geographically but, as will be shown, it is unquestionably one of the New World's most important archeological fields.

To begin at the very beginning, it is certain that somewhere in Guatemala there must exist remains of the earliest comers to the Americas. The Indians, we know, were present at the extreme tip of South America at a time when many sorts of animals now extinct were still in existence. To reach South America, their forebears must have worked their way down through Central America and Panama. Until very recently, however, no trace of early human occupancy of, or man's passage through, Mexico and Central America had come to light. But during the last 2 years crude implements and a human skeleton have been found in the Valley of Mexico in deposits which seem surely to date from very shortly after the close of the last glacial period. Discovery of similar evidence in Guatemala would add greatly to our at present extremely scanty information as to the peopling of the New World, and as to the culture possessed by the pioneers.

Where to seek such evidence is a problem. The Pacific coast plain, level, rich in game, its waters teeming with fish, would seem to have offered the most favorable route for migration. It surely so served in later times. However, to find the meager remains that hunters and fisherfolk and gatherers of wild foods can be expected to have left behind them will not be easy. The coast plain and the slopes of the volcanic coast range are deeply covered by alluvium washed down during the ages from the mountains. Early camp sites must, in most cases, lie far below the present surface. Not only that, but the shore line of today is evidently a considerable distance farther out than it was 10 or 15 thousand years ago. Random digging would

be useless. A sharp lookout should therefore be kept for materials which may become exposed by the cutting of streams or by road and other excavations. But the chances of an archeologist's happening to be on the spot to take advantage of such an accidental find are almost negligible.

Whether or not the highlands served as a route for early travel is unknown. They may well have been, and at any rate doubtless became inhabited a very long time ago. In the interior valleys there should accordingly exist remains dating from the very long period which elapsed between the first coming of man to Guatemala and the rise of agricultural, pottery-making cultures. This stretch of at least several millennia is at present entirely unrepresented by identifiable relics, not only in Guatemala but throughout Mesoamerica. In many parts of the highlands search for evidence of human life during those years will encounter the same difficulties presented by the coast. It is possible that the oldest sites may have been buried by falls of volcanic ash—incidentally, it is most important that studies be made to determine the age of the more recent volcanic deposits. And even if not blanketed by the original falls, such sites may well have been covered by ash washed down from the higher parts of the terrain. For this reason search should be made of areas not so affected, as on the northern and western slopes of the Cuchumatanes, in Alta and Baja Verapaz, and particularly in the valley of the Motagua and its tributaries. That drainage is a most promising region because, owing to its aridity, the ground is little hidden by vegetation; many quebradas present extensive cross sections through old deposits; and also because, in the Motagua country, there have often been found bones of members of the elephant family known to have been hunted by the early ancestors of the Indians in North America.

The next major stage in Mesoamerican culture development was that which saw the beginnings of settled agricultural life, a stage, theoretically, during which maize was first brought under domestication. This, again theoretically, should have been an era of small communities, possessing few of the attributes of the later, more advanced civilizations. Pottery, however, was presumably being made. I have said "theoretically" because no trace of these postulated first farmers has so far come to light in Guatemala or, for that matter, in any other part of Mesoamerica. That such a stage must have existed somewhere is obvious, because the oldest cultures we can now identify—the so-called Archaic of Miraflores and Salcája in Guatemala, Playa de los Muertos in Honduras, Zacatenco and Early Tres Zapotes in Mexico—are so highly developed that they can only have been the result of a long period of growth.

Were the above-mentioned Archaic cultures relatively uniform, one might suppose that they were introduced in mature form from South

America, but although they are more generalized than those of the Classic Period they nevertheless exhibit distinct local differences that seem to have evolved so-to-speak in situ. Furthermore, they are unlike any culture at present known from south of Panama. This problem of the early agricultural-pottery-making peoples is one of the most baffling which confronts the student of Mesoamerican prehistory. Guatemala should be a particularly favorable area for research on this important question because elements of the so-called "Q-complex" which, as Lothrop and Vaillant have pointed out, appear to underlie, or at least to have played some part in the evolution of the more southerly Archaic manifestations, are to be seen in both Miraflores and Salcaja materials. Search should accordingly be made for any culture of simpler type than Miraflores and Salcaja. If the Lothrop-Vaillant hypothesis is correct such a culture should contain an even higher percentage of "Q" traits.

It is, of course, to be hoped that the postulated early remains may be found in stratigraphic position below those of a recognized Archaic culture. That would definitely settle the matter of relative age. But enough work has been done at Kaminaljuyu to make it reasonably certain that at that site nothing older lies below Miraflores and two other closely related but slightly earlier Archaic phases known as Las Charcas and Sacatepequez; and, although the Salcaja deposits have been less carefully studied, there are no indications that they overlie anything more ancient. Both Kaminaljuyu and Salcaja, however, are in areas heavily blanketed by volcanic ash, the upper layers of which may be of sufficiently recent date to have rendered those localities unsuitable for agriculture during pre-Archaic times. It would therefore be well to investigate country upon which little or no ash has fallen. The northwestern slopes of the Cuchumatanes fulfill this requirement and they should certainly be explored, not only because of absence of ash but also because that region sustains an exceptionally luxuriant growth of teocinte, a plant which, whether one regards it as an ancestor or a bastard offspring of maize, is in some way connected with maize. Maize having been without question one of the very important food crops of Archaic times, and therefore presumably of pre-Archaic times, any area in which it might have been brought under domestication becomes important in our search for the origins of New World civilization.

With the opening of the Archaic Period we at last find ourselves on more solid ground, in that materials are abundant and their assignment to a pre-Classic era can be made not only on typological grounds, but on the incontrovertible evidence of stratigraphy. In Guatemala, as has been said, the Archaic is represented by Las Charcas, Sacatepequez, Miraflores, and Salcaja. Further work can be counted upon to reveal other Archaic cultures in the highlands and on the

Pacific coast. In Peten, also, Archaic remains have been found: the Mamom phase and the somewhat younger Chicanel of Uaxactun. These are of special interest because before their discovery it was generally believed that advanced culture had developed in the highlands and had not worked its way into the lowland jungles until a relatively late date. Now, however, it appears that Mamom may be even older than anything so far known in the highlands, for the closest resemblances between the Peten Archaic and that of the highlands are on the Chicanel, rather than the Mamom horizon. This raises the possibility that the beginnings of higher civilization may have to be sought in Peten. This will be no easy task because of the difficulty of getting about in that area and the practical impossibility of locating, in the dense tropical undergrowth, any archeological site not marked by mounds or stone structures, which, in all probability, were not erected by the first agriculturists. The Mamom and Chicanel deposits at Uaxactun would, for example, never have come to light had attention not been called to the site by the presence of its Classic Maya buildings.

Nothing earlier than Mamom apparently exists at Uaxactun but even more ancient remains may well exist at some of the many other ruined cities of Peten and no excavation at any one of them should be considered complete until pits have been sunk to bedrock in plazas and other places where possibly early refuse might have accumulated. It is difficult to choose any specific district for investigations looking to the discovery of lowland pre-Archaic, but one would suppose that the shores of the many lakes of Peten and the banks of such great rivers as the Usumacinta and Pasion would be promising locations.

To return to the Archaic proper, far too little is known of Miraflores or Salcaja; and Mamom and Chicanel are represented by materials from but a single site. More data are needed, both in the way of specimens and in the matter of distribution. As to the archeology of great stretches of country we are entirely ignorant. It is nevertheless becoming increasingly clear that the Archaic cultures were considerably more advanced than was formerly supposed. The people of that time were skilled potters and stone workers, they had already developed social and economic systems under which it was possible to carry out great communal undertakings. As evidence of this are a number of very large mounds at Kaminaljuyu that are certainly of Miraflores date and one on Finca Arizona near Puerto San Jose in the summit of which were found Miraflores tombs. Temple E-VII-sub at Uaxactun is believed to be a Chicanel structure. We must also believe that the remarkable hieroglyphic and calendrical systems of the Maya were evolved during the Archaic, for when the oldest dated stelae were erected at the beginning of the Classic Period,

those systems were in full working order. Where this took place is as yet unknown. Peten seems to be the most likely region, but the eminent Mexican archeologist Alfonso Caso has recently brought forward weighty arguments tending to show that bar-and-dot numeration, always thought to have been a Maya invention, may have been originated in Oaxaca, supposedly by the ancestral Zapotec¹; and if the very early date on the famous stela of Tres Zapotes, in Veracruz, has been correctly read and if it recorded a contemporaneous event, one might have to look to the southern coast of the Gulf of Mexico for the place of origin of the Maya calendrical system.

We now pass upward in time to the Classic Period, which saw the full flowering of Mesoamerican civilization in Guatemala, Honduras, El Salvador, and Mexico. It was once rather generally believed, because of the brilliance of this development among the Maya, that their culture preceded and stimulated such others as those of Monte Alban, Tajin, and Teotihuacan in Mexico, and of Tazumal in El Salvador. Finds of Early Classic Maya pottery at Teotihuacan and also in tombs at Kaminaljuyu, where it was associated with Teotihuacan pottery and a stone carving of unmistakable Tajin style, have suggested, however, that most, if not all, the Classic cultures came into being more or less simultaneously, each apparently growing out of a preexistent and already locally specialized Archaic forerunner. As to the chronological position of still another very important culture, the Olmec or La Venta of southern Veracruz and Tabasco, there is greater doubt, the distinguished Mexican artist and scholar Miguel Covarrubias believing it to have been earlier than, and in some respects ancestral to, those just listed. Other students feel that Olmec was probably contemporaneous with them.

This problem and many others have been really little more than formulated. Much exploration, excavation, and comparative studies of ceramics, stone artifacts, jade carving, and major stone sculpture must be carried out before satisfactory solutions can be reached. In all such research Guatemala is destined to play a most significant role because of the abundance of its ancient remains and also because, throughout its long pre-Columbian history, parts at least of Guatemala served as a highway for migration and trade.

Archeologically speaking, Guatemala, of the Classic Period may, like Gaul, be divided, very roughly, into three parts: the northern lowlands, the highlands, and the Pacific coast. The northern lowland province consists of the Department of the Peten, and British Honduras, with limited extensions into the Mexican states of Campeche and Chiapas. The Peten is its heart, both geographically and culturally. In Peten lie Piedras Negras, Altar de Sacrificios, Uaxactun, Holmul, Xultun, Naranjo, and Tikal, the greatest of all ancient Maya cities.

¹ A. Caso, "Calendario y Escritura de las Antiguas Culturas de Monte Alban." Mexico, 1947.

Close to the border, in Chiapas, are Yaxchilan, Palenque, as well as Bonampak, whose remarkable mural paintings have been recorded by Sr. Antonio Tejeda F. and the Mexican artist Villagra. According to the evidence now available, the brilliant Classic Maya civilization had its origin in north-central Peten and spread outward from that center.

In spite of the extreme difficulty of travel in its dense tropical jungles, the archeology of Peten is better known than that of any other part of Guatemala. This is of course due to the presence there of the above-mentioned and many other Classic Maya sites whose spectacular ruined temples and wealth of hieroglyphically inscribed stelae have, until very recently, almost monopolized the attention of students. More excavation has also been carried on there—particularly at Piedras Negras and Uaxactun—than in all the rest of the Republic. Nevertheless, a vast amount remains to be done. Many important cities doubtless still await discovery in the vast forests; others, already located, have only superficially been studied. Work anywhere in Peten would be valuable, but certain specific investigations are urgently needed. The search for and exploitation of Archaic and pre-Archaic remains has already been mentioned. Among the Classic sites, Altar de Sacrificios, a very large and evidently long-occupied city, especially calls for attention because of its situation at the junction of the Pasion and Salinas Rivers, which makes it probable that it received trade from north-central Peten, from the Usumacinta cities, and, via the Salinas drainage, from the highlands. Excavations at Altar de Sacrificios should yield much-needed information as to cultural and chronological relations between the various lowland Classic centers and between them and various centers in Quiche, Huehuetenango, and Alta Verapaz. Another strategic point is Lake Peten where, at Tayasal, are Classic ruins and where, presumably on the present site of modern Flores, the Itza remained independent and practiced the ancient Maya culture until the end of the seventeenth century.

It is to be hoped that Tikal may some day be cleared and maintained as a national park. This city, as has been said, was the greatest of all Maya cities. Its scores and scores of structures of all sorts, many in remarkably good preservation, are dominated by steep and towering pyramids, each crowned by a tall roof-combed temple. If sufficient vegetation were removed to render the buildings visible—they are now literally buried in dense bush—and if a landing field were provided, Tikal would become one of the world's most famous monuments of antiquity. And judging by the wealth of fine specimens found at nearby Uaxactun, which was really little more than a suburb, the material to be recovered from tombs and caches of Tikal would be

of the utmost archeological and artistic importance. The work, however, would be long and costly. A tremendous amount of labor would have to go into the mere felling of the forest. And the jungle growths once removed, the pyramids and temples would have to be stabilized, for the tree roots, which in past ages have caused such destruction, now serve to hold and bind together the masonry of walls and terraces. For this reason, no project should be undertaken at Tikal until a thorough and definitive piece of excavation and repair can be assured.

In so brief a summary as this of the archeological riches of Guatemala and of their scientific significance, it is impossible to do more than outline a few of the manifold problems of the lowland area. Those of the origin of Maya civilization have already been glanced at, and it was assumed that it arose from a local Archaic base in north-central Peten. The outward sweep of Maya culture seems to have been comparable to that of Christianity over early medieval Europe, that is to say, a diffusion to already resident and probably Maya-speaking populations of a religious cult, with linked ceremonial, artistic, architectural, and intellectual attributes, rather than a spread of people. Although this is somewhat of an assumption, it seems to be borne out by divergences from Peten practice in the more everyday aspects of material culture, such as milling stones, common household pottery, etc., which are to be seen in the Motagua Valley, at Copan, on the Usumacinta, and in Yucatan, all areas into which, if we have correctly interpreted the evidence of the dated stelae, Maya ceremonialism penetrated from the Peten nucleus.

What stimulated the development of the extraordinary Maya cult and what factors conditioned its wide acceptance will probably never be revealed to us, but as to the life, the arts, the architecture, the calendar, and the hieroglyphic writing of the Maya, we already have considerable knowledge, and further work in the as yet almost untouched wealth of ruins in Peten and adjacent regions will yield a rich harvest of new information. We may also learn whether the entire territory occupied by peoples of Maya culture was under the sway of a central government, in other words whether the "Old Empire" was indeed an empire; whether it was loosely bound together in some sort of confederacy; or whether, like ancient Greece, it was divided into independent city states. At all events, the southern cities were in existence for some six centuries before they were abandoned and the once populous Peten reverted to jungle. Why this should have occurred has not as yet been satisfactorily explained.

So much—and it is little enough—for the lowlands of northern Peten. Between them and the highlands is the vast and also densely forested sweep of southern Peten, a little-explored region which seems never to have been heavily populated.

The highlands were also occupied by Maya-speakers, sturdy, independent folk, to judge from their present-day descendants. Culturally they never reached the heights attained by their lowland linguistic relatives. Very little is yet known of highland archeology. Sites are abundant, but because few of them contain well-preserved buildings, they have generally failed to attract the efforts of students. The lack of striking architectural remains was believed by Manuel Gamio to have been due to prevalence of earthquakes which would have rendered unsafe any masonry structure the ancients were capable of erecting. Stone buildings did, however, exist, particularly in the northwestern highlands, but none in that area carried the corbelled vault and, seemingly because of the difficulty of working the hard volcanic rocks of the highlands, none are of cut stone. The majority of sites therefore now consist of earth mounds that formerly supported temples of perishable materials, as at Kaminaljuyu; or of stone substructures and fragments of walls that time and weather have largely stripped of their original stucco facings as at Utatlan and Zaculeu. For this reason there has, until recently, been no ruin illustrating the architectural achievements of the ancient people which is easily accessible to the people of Guatemala and to tourists. Now, however, through the interest of the United Fruit Company, Zaculeu, former capital of the Mam nation, easily reached from Huehuetenango, has been excavated and many of its principal buildings restored.

Although Guatemala highland ruins are, in their present state, unspectacular, they contain materials of the greatest archeological importance because, far more than Peten, the highlands were open to influences from east and west as well as to actual incursions of outsiders. Valuable evidence can thus be gathered there, as was the case at Kaminaljuyu, regarding the chronological and commercial relations between many Mesoamerican groups.

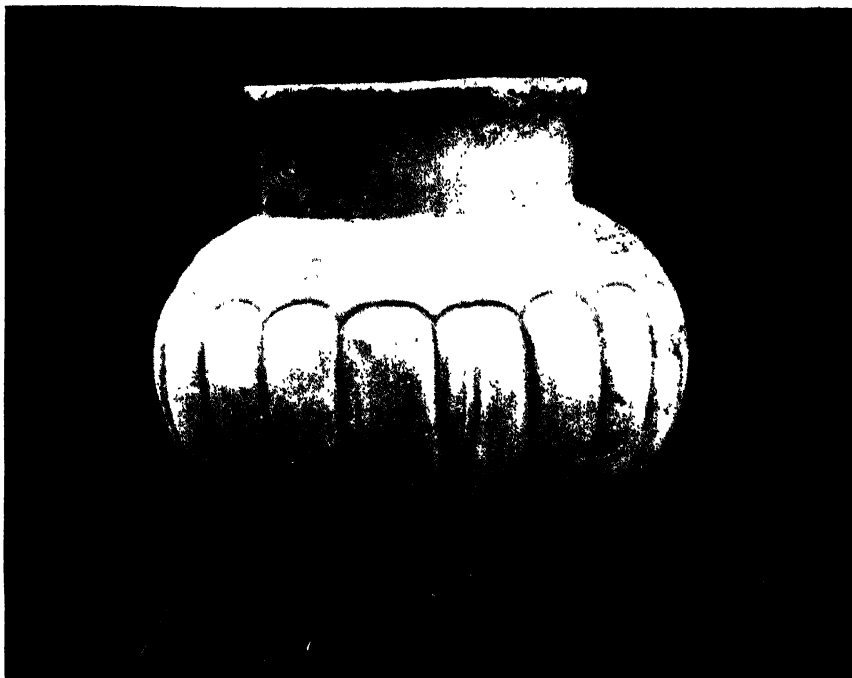
In the highlands, no less than in Peten and other parts of Mesoamerica, a remarkable burst of cultural energy ushered in the Classic Period. Kaminaljuyu was in its prime. At Nebaj, at Chalhitan near Aguacatan, at Zaculeu, at Zacualpa, and elsewhere are extensive assemblages of mounds dating from this era. It seems to have been a relatively peaceful time, for all the known large Classic sites except Zaculeu were located without reference to defensibility. Trade was brisk and far-reaching. Objects from central Mexico, the Gulf coast, the Peten, and El Salvador have been found at Kaminaljuyu; and, at Nebaj, pottery from Peten and jades probably carved on the Usumacinta.

Even in those early days, influences from Mexico had begun to appear. It may even be that there were actual migrations from the north. At a later time movements of people from Mexico certainly took place. Evidence of this is found in such legendary accounts as the Popul Vuh, in the presence of groups of Nahuatl-speaking Pipil on the coast, on the Motagua, and in what is now Baja Verapaz. It has been suggested that warlike Mexicans may have been responsible for the disturbed conditions and intertribal strife that occurred throughout the highlands between the close of the Classic Period and the coming of Alvarado. That such conditions existed is indicated by the fact that sites of that period, such as Utatlan, Chuitinamit on Lake Atitlan, Iximche, Chutix Tiox near Sacapulas, and many others in the Departments of Quiché and Huehuetenango were situated with an obvious eye to protection from attack. Furthermore, the Popul Vuh and the Annals of the Cakchiquels are full of accounts of battles and sieges.

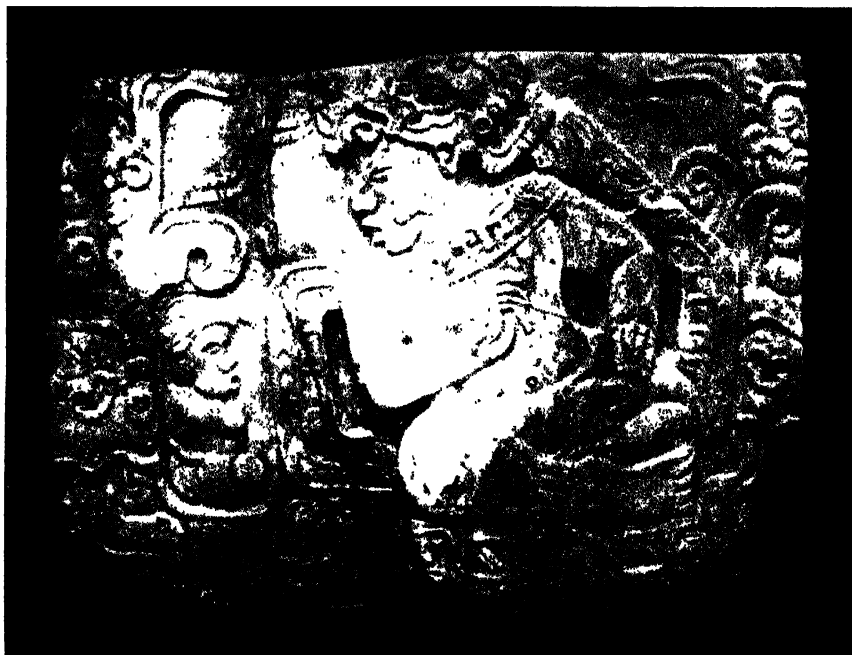
What was going on in Alta Verapaz at this time is less understood. During the Classic Period that area received strong influence from the Lowland Maya, as is shown by the beautiful pottery found there. As to events of the later prehistoric era we know next to nothing. Queerly enough, there seem to be relatively few large ruin groups in Alta Verapaz; but almost no archeological work, even surface reconnaissance, has been done.

Although our knowledge of the highlands is scanty, we are in even worse case as regards the Pacific slope and coastal plain. That wonderfully fertile strip of country between the volcanic rampart and the ocean probably contains more ancient remains per square kilometer than any other part of the Republic. Sites, for the most part assemblages of earth mounds—there seems to have been very little stone construction at any period—are everywhere; and, even more than the highlands, the coast was easily accessible to influences and migrations from without. There is evidence of a heavy population during Classic times, but little is known of Classic coastal culture, save for a rather late phase represented at Finca El Paraiso, in the Chuva district. A little work has also been done at El Baul, where there occur most interesting sculptures, including a colossal stone head. Other sculptures, some showing strong Mexican traits, have been found at Santa Lucia Cotzumalhuapa. Elsewhere, carvings in Olmec style have come to light. It is certain that a stock taking of coastal remains, followed by excavations at sites which such a survey shows to be strategic, would yield a rich harvest of information, not only as to Guatemalan pre-history but also upon problems of continent-wide importance.

Enough has been said to make clear the vast archeological wealth of Guatemala. Its antiquities are a precious heritage from the past; they also constitute a vital chapter in the story of human civilization, of man's slow and painful conquest of nature, of his unremitting struggle for a better and fuller life, a struggle which began with the Stone Age and is still going on.



1. ALABASTER VASE FROM A TOMB AT NEBAJ IN THE HIGHLANDS



2 CARVED JADE FROM A CEREMONIAL CACHE AT NEBAJ
One of the finest pieces of its kind that has come to light.

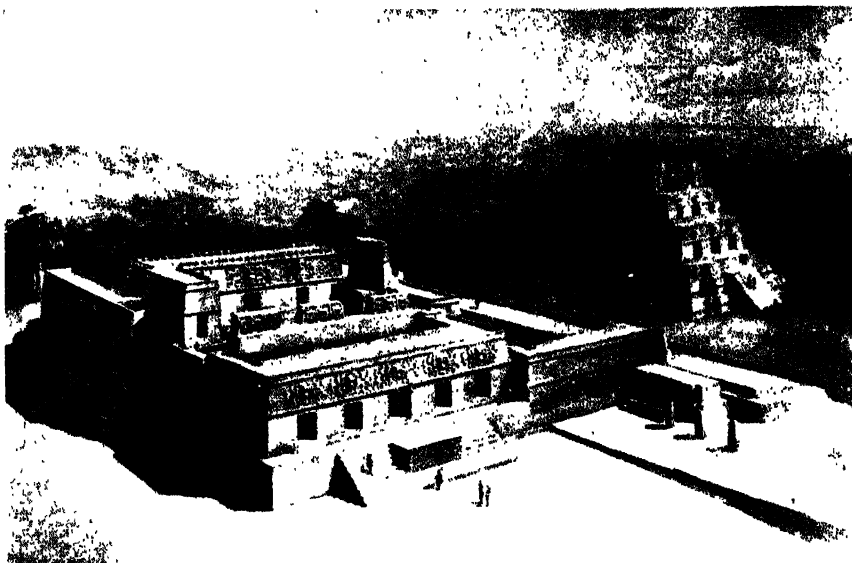


1. AIR VIEW OF A TEMPLE AT UAXACTUN IN THE PETEN JUNGLE

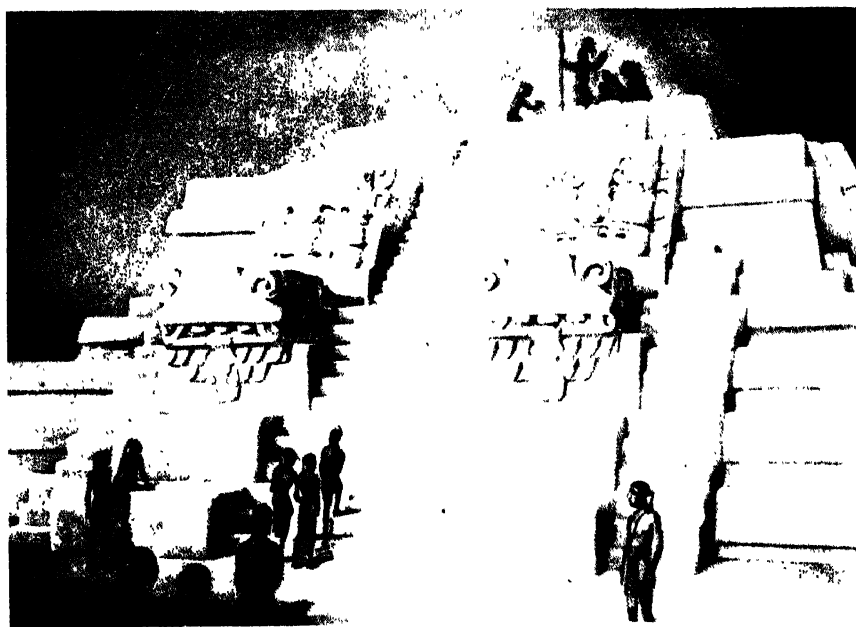


2. GENERAL VIEW OF UAXACTUN

Restoration drawing by Tateania Proskouriakoff.



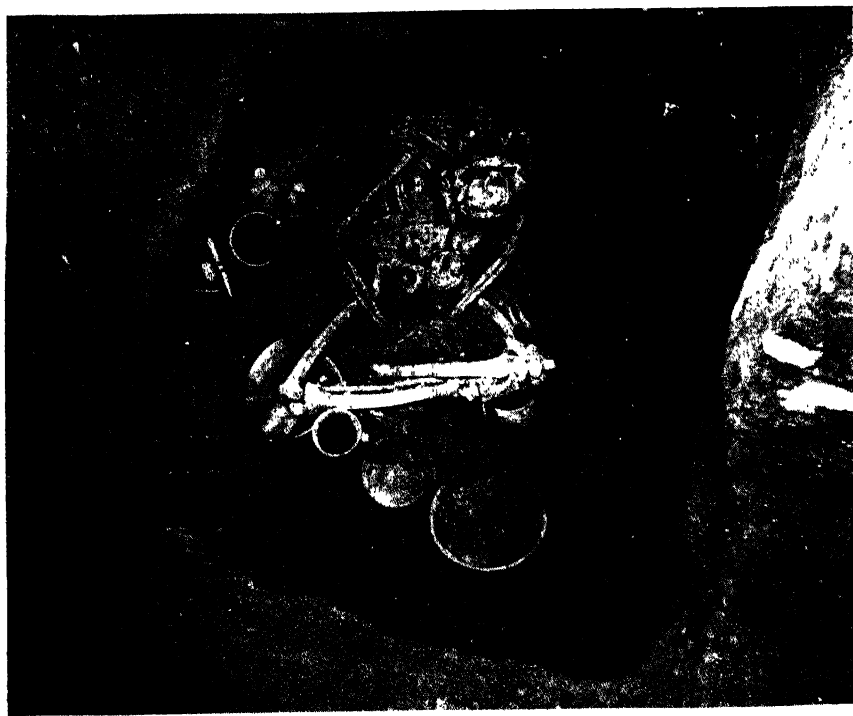
1. THE "PALACE," UAXACTUN
Restoration drawing by Tateania Proskouriakoff.



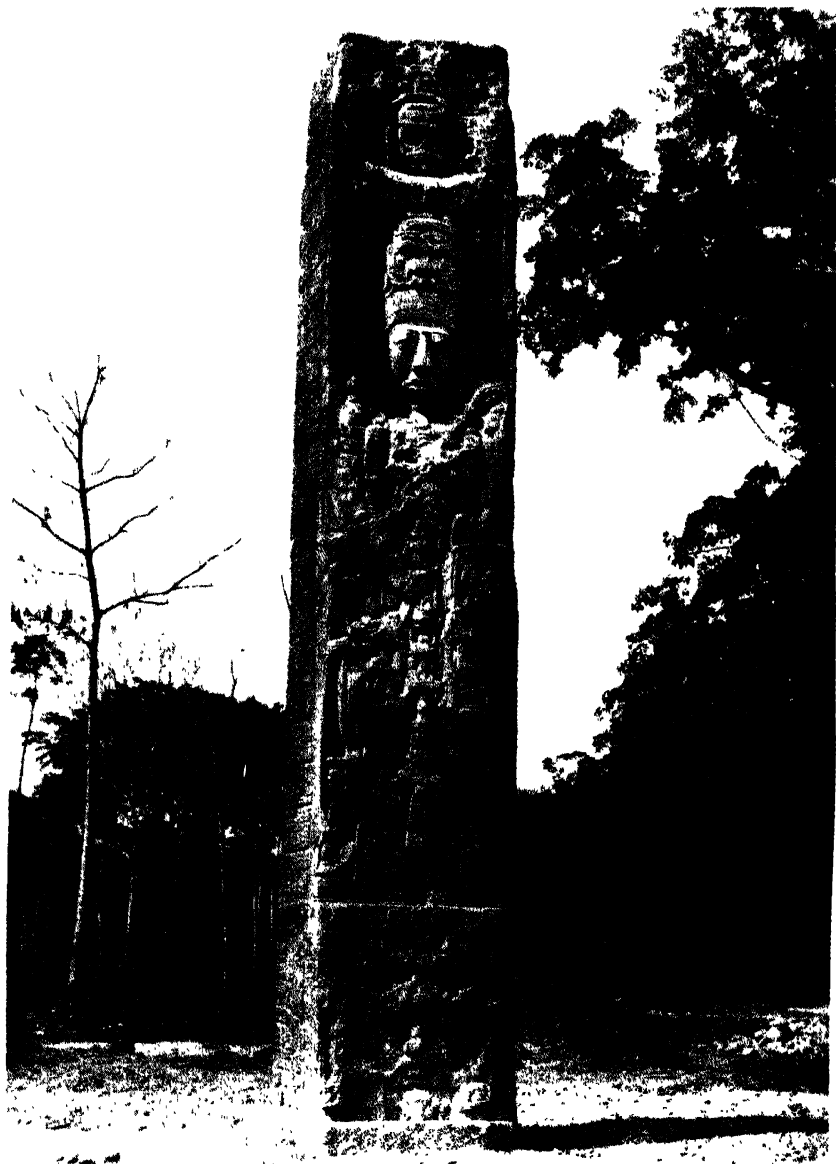
2. TEMPLE E-7-SUB, UAXACTUN
Restoration drawing by Tateania Proskouriakoff.



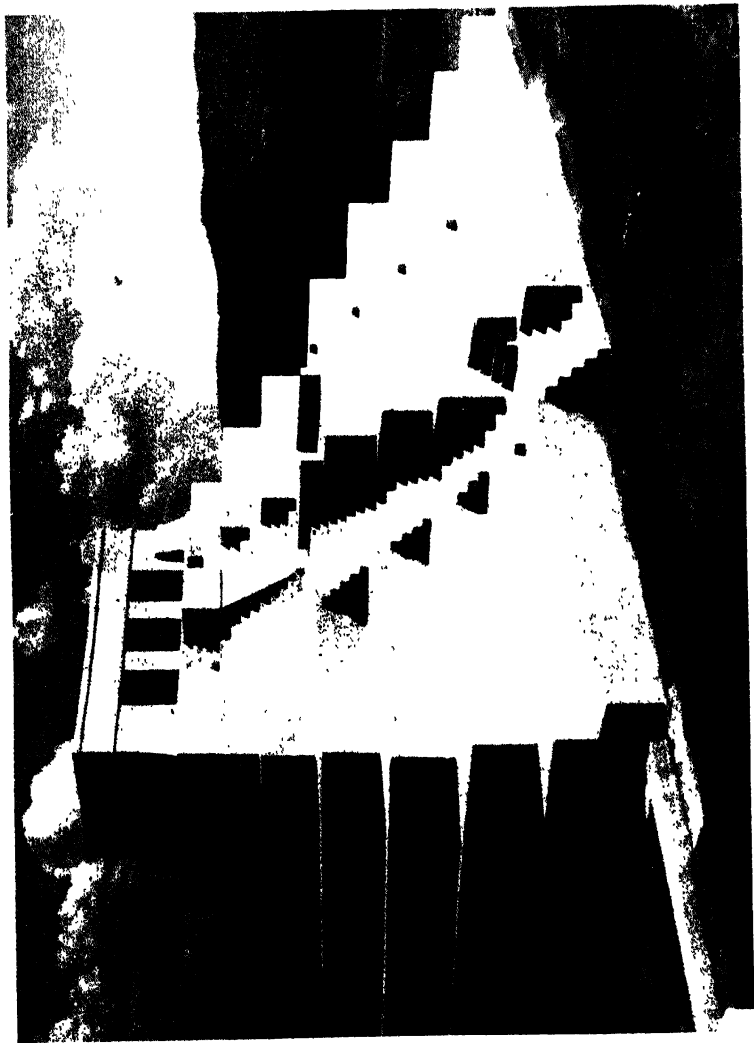
1 EXCAVATION AT KAMINALJUYU, NEAR GUATEMALA CITY, SHOWING REMAINS OF A LATE STRUCTURE COVERING THE WELL-PRESERVED STAIRWAY OF AN EARLIER ONE



2. GRAVE OF THE CLASSIC PERIOD AT KAMINALJUYU



STELA E AT QUIRIGUA, THE TALLEST MAYA STELA KNOWN



PYRAMID AND TEMPLE AT ZACULEU, AS RESTORED BY THE UNITED FRUIT COMPANY
A typical example of highland architecture.

EXCAVATIONS AT THE PREHISTORIC ROCK-SHELTER OF LA COLOMBIÈRE¹

BY HALLAM L. MOVIUS, JR.
*Curator of Palaeolithic Archaeology,
Peabody Museum, Harvard University*

[With 7 plates]

INTRODUCTION

The primary objective of the expedition sent out in 1948 by the Peabody Museum of Harvard University to eastern France was to attempt to date the time when an Upper Paleolithic locality in the Southern Jura region was occupied by our Stone Age ancestors. This problem, fundamental to the establishment of a reliable chronology for the classic sequence of Old Stone Age cultures in western Europe in terms of the advances and retreats of the Alpine glaciers (see chart, fig. 1), was approached by means of combined archeological and geological field work.

The dating of archeological deposits by means of geology is based on a detailed study of stratified layers of sand and gravel which were laid down by the action of rivers flowing from the glaciated regions. These sand and gravel deposits were built up into the form of terraces by the waters which flowed from the glaciers. The latter pushed thousands of tons of debris—called moraines—ahead of them, and during the warm seasons of the year, when the ice was melting, there was an abundant supply of this material piled up at or near the edge of the ice that was available for transport by the rivers. The rivers in turn carried this material away, and deposited it in the base of the valleys, through which they were flowing, in the form of terraces.

In order to find a locality where combined archeological and geological field work could be expected to furnish fresh facts bearing on the problem of Upper Paleolithic chronology, it was not necessary to conduct an extensive program of reconnaissance. Just before the first World War commenced, Dr. Lucien Mayet of the University of Lyon and M. Jean Pissot of Poncin (Ain) partially excavated the large rock-shelter of La Colombière.² This site (pl. 1) is located in the Department of Ain, some 45 miles northeast of Lyon and near

¹ Reprinted by permission from *Archaeology*, vol. 2, No. 1, March 1949.

² Mayet, Lucien, and Jean Pissot, "Abri-sous-roche préhistorique de La Colombière, près Poncin (Ain)," *Ann. Univ. Lyon*, ser. 1, vol. 39, pp. 1-205, 1915.

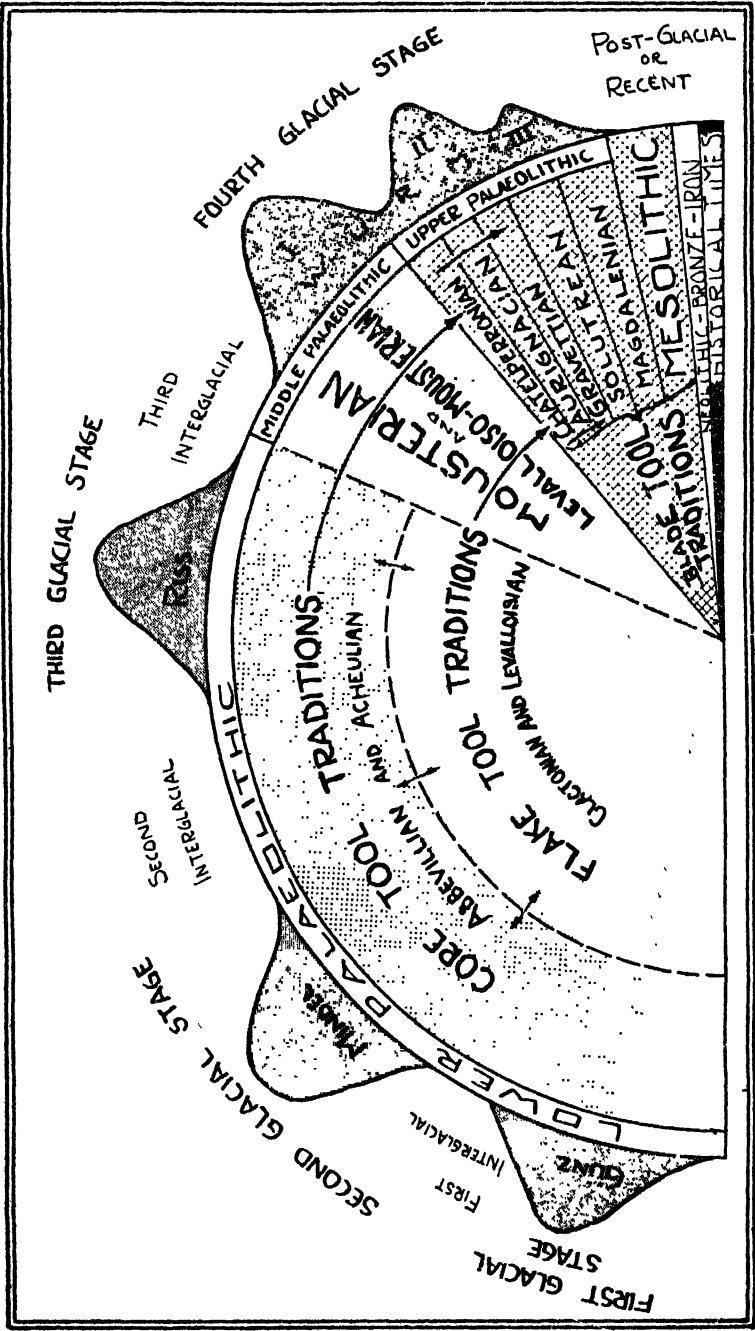


FIGURE 1.—Chart of the Pleistocene Epoch, or Ice Age, showing glacial stages and the contemporary cultural development of early man. (For explanation see p. 363)

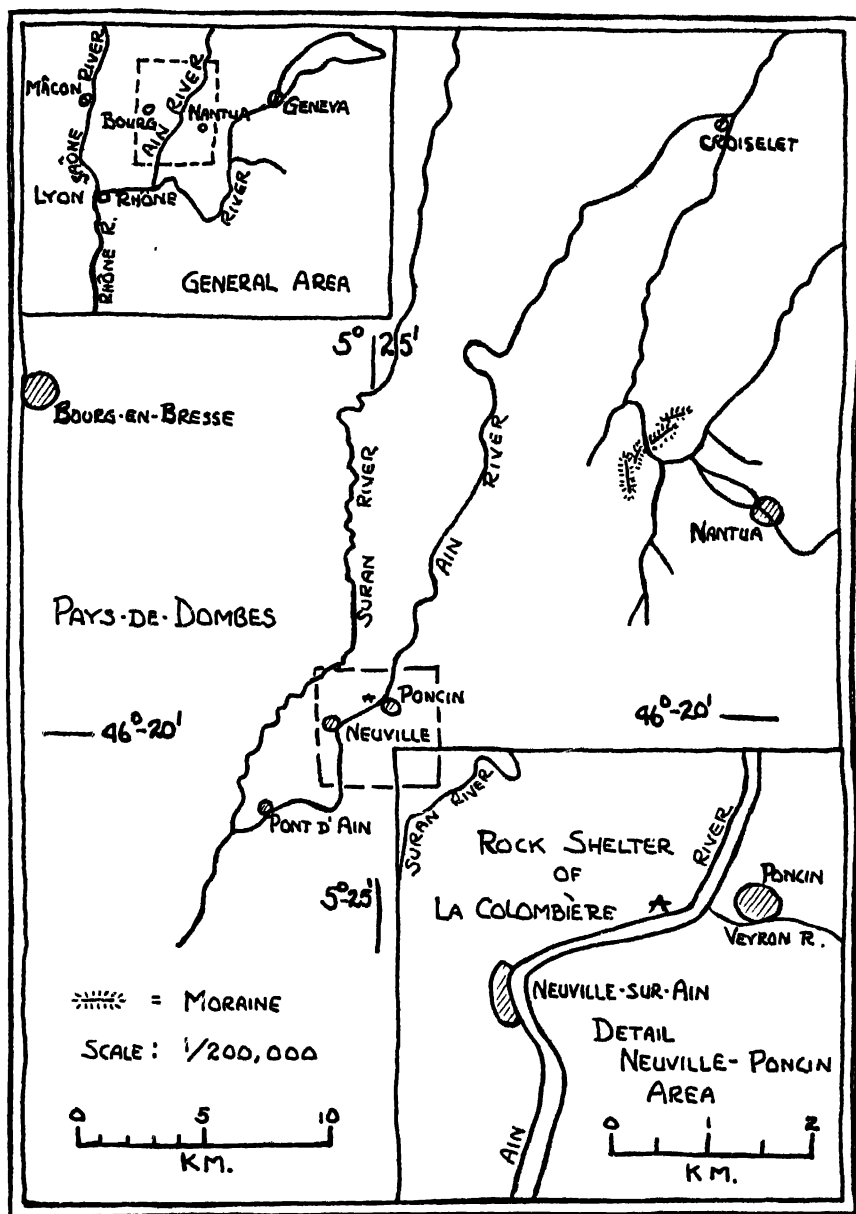


FIGURE 2.—Map showing location of La Colombière and places mentioned in the text.

the town of Poncin, in the valley of the Ain River (see map, fig. 2). It is in this region that the river emerges from the Jurassic limestone foothills of the Southern Jura onto the flat, marshy plains area, known as the Pays-de-Dombes.

Now, as may be clearly observed in several of the fine photographs published by Mayet and Pissot, the basal deposits in the La Colombière rock-shelter consist of river-laid sands and gravels that form part of the 20- to 23-meter terrace of the Ain (pl. 2), which has a wide distribution in the region. Presumably during the warm months of the year, Upper Paleolithic hunters moved into this section of the Ain Valley and actually camped on the surface of this terrace, which more than half fills up the area protected by the overhanging rock at La Colombière. They left behind various types of flint implements—knives, points, scrapers, and engraving tools—as well as several objects with drawings of animals engraved on them, and the bones of the game they hunted.

These vestiges of a Stone Age occupation are found in direct association with extensive fire hearths in the uppermost levels of the terrace referred to above. In other words, the earliest habitation layers at this site, which consist of two gravel horizons (D_1 and D_2 in pl. 2), are intimately and directly tied in with the final stages of deposition by the river. These so-called "D" layers in turn were separated from the overlying Magdalenian horizon³ (indicated as B on the section) by a thick deposit of sterile sand, there having been no Solutrean occupation⁴ here.

The two primary objectives of the 1948 expedition of the Peabody Museum of Harvard University to eastern France, therefore, were:

(a) To excavate the rock-shelter of La Colombière, near the town of Poncin (Ain); and

(b) To investigate the extensively developed Late Pleistocene terraces of the Ain Valley for the purpose of dating the main occupation layer at La Colombière in terms of the local glacial sequence.

Both of these objectives were successfully accomplished.

This work was made financially possible by a substantial grant from the Viking Fund of New York for which we are profoundly grateful. We would also like to take this opportunity of thanking the Commission of Historic Monuments, Ministry of National Education, Republic of France, which very generously gave its authorization for the expedition to undertake the excavation of La Colombière. This permission was granted to the writer under the same conditions as those normally established for French archeologists.

WORK OF THE 1948 SEASON

The excavations at the rock-shelter of La Colombière were begun on June 10 and completed on August 20, 1948. In this 10-week period the remaining archeological deposits at the site were completely

³ This layer was completely excavated by Mayet and Pissot during their 1912-13 season.

⁴ The type station of the Solutrean culture, Solutré (Saône-et-Loire) is located near Macon, less than 35 miles due west of Poncin.

dug, with the exception of a test section approximately 2 meters square left at the request of Dr. Franck Bourdier, Regional Director of Prehistoric Antiquities, and a small, apparently sterile area at the extreme eastern end of the shelter.

The personnel of the expedition was as follows: Dr. Kirk Bryan, Professor of Physiography, Harvard University; Dr. S. Sheldon Judson, Jr., Department of Geology, University of Wisconsin; Louis Dupree, Harvard University; Carleton Pierpont, Harvard University; and the writer. Professor Bryan was assisted in the geologic field work by Dr. Judson, while the writer had Messrs. Dupree and Pierpont as his assistants during the digging of the site.

The rock-shelter of La Colombière is 46 meters long and some 12 meters wide in the approximate center of the site below the maximum projection of the rock overhang. When we arrived there on the 8th of June 1948, not only was the place overgrown with small trees and shrubs, but also it was impossible to see across it, owing to the presence of several enormous boulders and piles of earth. The former had fallen from the roof of the shelter during prehistoric times; the latter consisted of M. Pissot's rather extensive dumps.

When the tedious work of clearing away this refuse had been completed (pl. 3, fig. 1), the limits of the areas previously excavated could be established. As the result of finding the edges of the trench dug in 1912-13 in the eastern portion of the site, it was possible to identify accurately the various levels originally reported by Dr. Mayet and M. Pissot (compare pl. 2). During the course of these clearing operations, Dr. Judson successfully completed a detailed topographic map showing La Colombière and the adjacent region.

From the outset the chance that the rock-shelter had been occupied during the interval immediately preceding the deposition of the 20- to 23-meter terrace (i. e., prior to the invasion of the site by the river) was considered a good possibility. It was also believed likely that what appeared to be the top of a filled-in lower cave (see pl. 3, fig. 1) might yield evidence of an earlier, and possibly even more interesting, occupation. But the hoped-for lower cave failed to materialize, and there was no evidence whatsoever of an occupation layer underlying the deposits in question.

Bedrock was finally reached at a depth of 11.85 meters, and a magnificent section was exposed through the tightly packed and fine-grained terrace deposits, which consisted entirely of sands and silts, with a basal layer of coarse sand and gravel (pl. 3, fig. 2, and pl. 4, fig. 2). Throughout, a very interesting fauna, especially rich in small vertebrates and also containing a few mollusks, was collected.

Abundant soil samples were taken for analysis, and it is hoped that on the basis of these the presence of a microfauna, as well as pollen (in the silty and clayey layers), will be demonstrated. It is felt that

detailed studies of the fauna and the soil samples will yield interesting and important data on the environmental conditions that prevailed in the region during the time when the La Colombière terrace was being formed.

While the deep central trench was being driven through to the bed-rock at the archeological site, Professor Bryan and Dr. Judson made an intensive study of the Late Pleistocene deposits of the Jura region in the vicinity of La Colombière. This work led to an extremely satisfactory and convincing tie-in of the 20- to 23-meter terrace of the Ain with a series of well-marked end-moraines near Nantua, a town approximately 11 miles due northeast of Poncin. In order to accomplish this it was necessary to leave the Ain Valley at the town of Croiselet and follow the valley of the Oignin River southward to the Nantua Basin. In this manner it was definitely established that the La Colombière terrace was formed at the time when the front of the glaciers was located near Nantua. This may certainly be regarded as a late episode during Würm (Fourth Glacial) times, but on the basis of the present evidence it is impossible to be more precise.

As regards the Upper Aurignacian occupation layers overlying the 20- to 23-meter terrace of the Ain at La Colombière, it was not only possible to identify all the levels reported by the original investigators of the site (see pl. 2), but also to establish the intimate and direct association of them with the uppermost portion of the thick deposits of river-laid sands and silts so clearly exposed in the main central trench. Very fine sections (pl. 4, fig. 2) clearly showing this relationship were revealed in both the western and the eastern portions of the site. In the latter sector the main occupation layer was for the most part intact. Although rich Upper Aurignacian (Gravettian) deposits were reported by Mayet and Pissot in the former locus, almost no archeological material was found there during the course of the 1948 season. The deposits in the eastern half of the rock-shelter, however, proved to be very much richer.

As previously stated, the Magdalenian⁵ layer was completely removed during the 1912-13 season by Dr. Mayet and M. Pissot; nevertheless a small patch of gravels that had accumulated during Late Pleistocene times was found in the base of a cleft in the rear wall of the eastern part of the site. In addition to a small collection of vertebrate remains, these gravels yielded the broken piece of an interesting broken bone object (pl. 5, fig. 1), which is possibly the perforated end of a so-called "bâton de commandement." In any case, the geometric decoration—chevron pattern, crossed on one side by parallel lines—is typically Magdalenian. The object, which is

⁵ The Magdalenian is a prehistoric culture which attained the peak of its development during the closing stages of the Ice Age, some 10,000 years or so after the Aurignacian.

2½ inches (6.6 cm.) long, is broken at both sides of a well-made hole, and it is the only example of Magdalenian art ever found at La Colombière.

In the actual Upper Aurignacian occupation layer a typical assemblage of flint tools, including several Gravette points, was found at the extreme eastern end of the site. Furthermore, a large quantity of broken flints and animal bones was unearthed in the vicinity of a fairly extensive series of hearths that came to light in the east-central portion of the site. In definite and direct association with this hearth complex an outstandingly fine art object—a very beautifully engraved pebble—was discovered (pl. 5, fig. 2).

Of the five or six superimposed animals on each surface, the extremely naturalistic horse, shown in the upper photo in plate 6, is the most easily recognizable. But there are also a second horse, a very finely drawn reindeer (with shed antlers), an ibex, a woolly rhinoceros, two carnivores (possibly bear), as well as several as yet unidentified animals (pls. 6 and 7). It is considered to be one of the finest examples of an Aurignacian engraved object that has ever been found, and constitutes a find of great importance from the point of view of Upper Paleolithic art. Unfortunately it has been broken at one end. It has been made a national antiquity by the French Government. For study purposes the Ministry of National Education of the Republic of France has graciously permitted the expedition to bring this singularly fine object to the Peabody Museum of Harvard University.

TENTATIVE CONCLUSIONS

On the basis of the results achieved to date, it is possible to state that the earliest occupation of the rock-shelter of La Colombière was effected immediately following the deposition of the 20- to 23-meter terrace in the Ain Valley, an event that occurred during Late Glacial times, when a tongue of the main Rhône Valley glacier was stationary at a line clearly marked by a series of end-moraines across the Nantua Basin. The first inhabitants of this site were people who possessed a very typical Upper Aurignacian (Gravettian) culture. At this time the river, which was incising itself into a flood plain on the present +20- to +23-meter level, still occasionally flooded the site during seasons of high water. In terms of glacial chronology, this was during the beginning of the retreat of the late Würm ice from the Nantua moraines. On this basis, La Colombière is the first Upper Paleolithic occupation site in France to be geologically dated.

At the time these Upper Aurignacian hunters moved into the Jurassic limestone uplands of the Southern Jura, cold grassy steppe conditions prevailed in the Ain Valley. The region supported a rich grazing fauna which thrived in a climate characterized by fairly

warm summers, severe winters probably with much snow, and short spring and fall seasons; in other words, an environment very similar to that which exists today in the northern portion of Europe.

Neither the relatively small series of flint implements recovered at La Colombière, nor the total number and thickness of the fire hearths, in comparison with other Upper Paleolithic sites in western Europe, suggests that this rock-shelter was ever permanently occupied. Furthermore, during the wet summer of 1948 it was found that the roof "leaked" very badly. This unpleasant feature, coupled with the fact that during Late Pleistocene times weathered-off fragments of limestone must have been constantly falling from the top and sides of the shelter, would not have been an inducement to settlers to occupy the place permanently. On this basis, it is concluded that the site was used only as a temporary camping place during the hunting season.

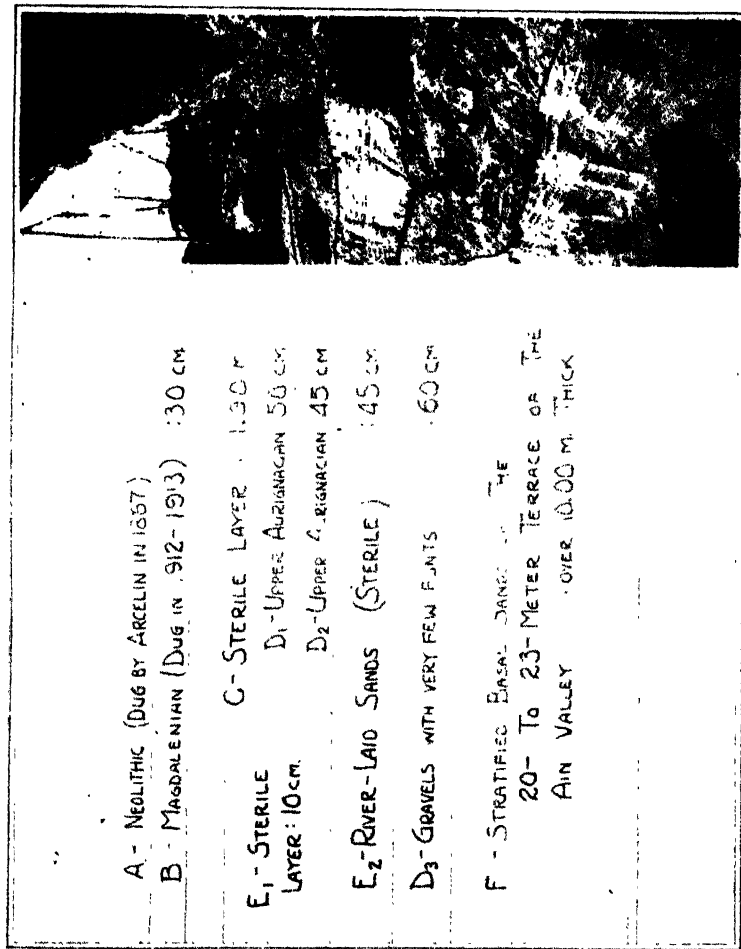
Finally, why are there so many animals superimposed on the two surfaces of a single pebble that measures only $4\frac{1}{4}$ inches long, $3\frac{1}{4}$ inches wide, and $1\frac{1}{8}$ inches thick ($12 \times 8.2 \times 3.5$ cm.)? In providing an answer to this question it seems difficult to avoid putting forward the suggestion that, in the eyes of the prehistoric occupants of La Colombière, this pebble was probably regarded as a hunting talisman rather than an art object. For there are thousands of similar water-worn limestone pebbles strewn on the floor of the Ain Valley near La Colombière. Surely, if an Upper Aurignacian artist had simply wanted to reproduce in the form of an outline drawing one of the animals his group was hunting (i. e., art for art's sake), it would be logical to expect him to select a new pebble with a fresh surface each time he desired to depict a new animal.

Therefore, it is probable that there was some definite reason for superimposing so many animals on a single pebble, and on this basis it is felt that the only plausible explanation is to regard the object as having importance in connection with certain magico-religious rites performed in connection with the chase. Thus we can imagine that the pebble was initially engraved and used in a hunting ceremony. Since that particular hunt was successful, the pebble was reengraved and used on subsequent occasions for the same purpose. It possessed magical qualities, or "mana." It is therefore tentatively concluded that the primary significance of this very fine object, from the point of view of the people who actually lived at La Colombière during the closing phases of the Ice Age, was not the beautiful engravings so carefully executed on its surfaces, but the fact that it was the medium by which it was possible to commune directly with the spirits of the animal world for the purpose of successfully replenishing the all-important food supply.

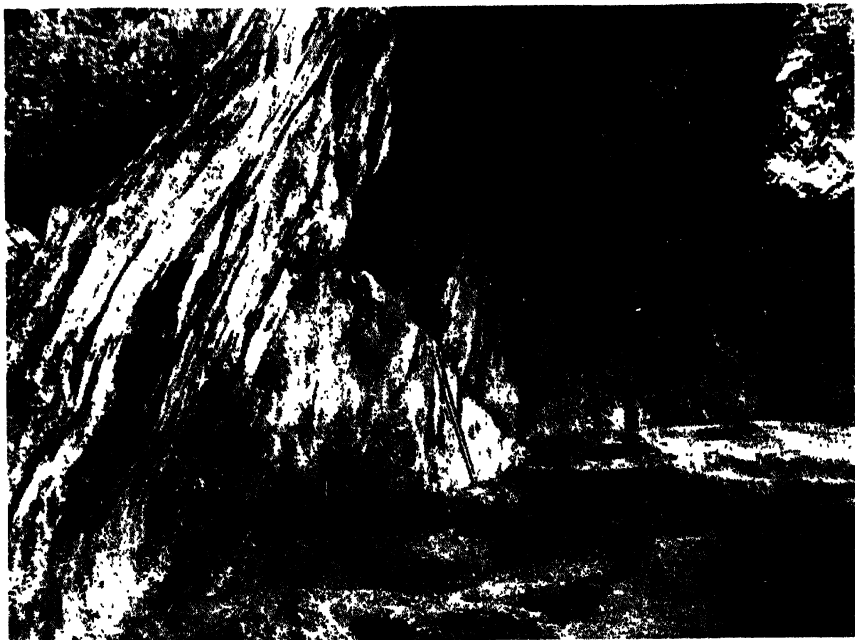


GENERAL VIEW OF THE ROCK-SHELTER AT LA COLOMBIÈRE

(See explanation of plates, p. 367.)



STRATIFICATION OF ROCK-SHELTER AT LA COLOMBIÈRE
(See explanation of plates, p. 367.)



1. THE SITE LOOKING EAST
(See explanation of plates, p. 367.)



2. TRENCH DUG THROUGH RIVER-LAID TERRACE DEPOSITS AT LA COLOMBIÈRE
(See explanation of plates, p. 367.)



1. MAIN TRENCH NEAR REAR WALL OF ROCK-SHELTER
(See explanation of plates, p. 367.)



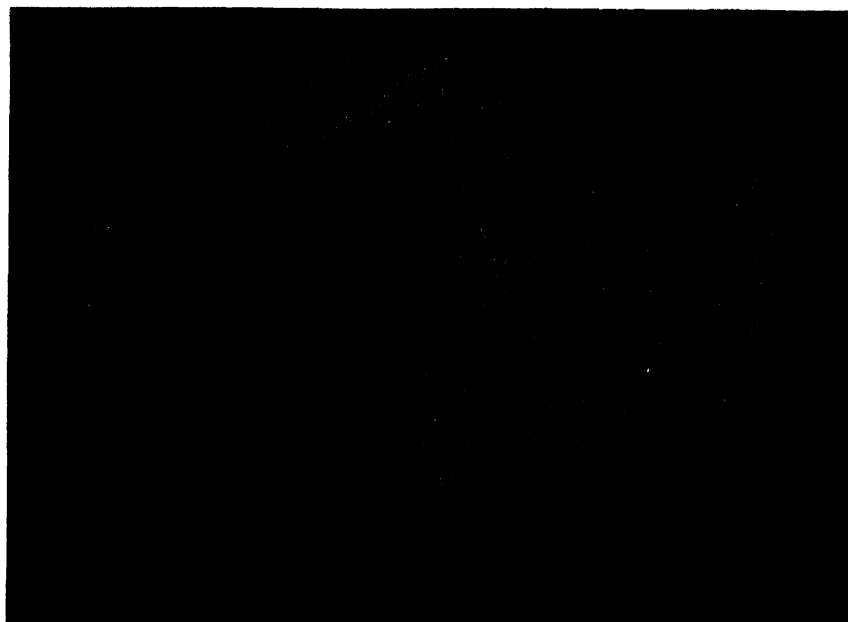
2. SECTION NEAR WESTERN END OF LA COLOMBIÈRE
(See explanation of plates, p. 367.)



1. BROKEN MAGDALENIAN BONE OBJECT FOUND AT LA COLOMBIÈRE
(See explanation of plates, p. 367.)

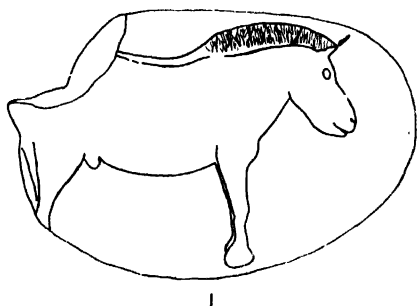


2. ENGRAVED PEBBLE FOUND AT LA COLOMBIÈRE
(See explanation of plates, p. 367.)

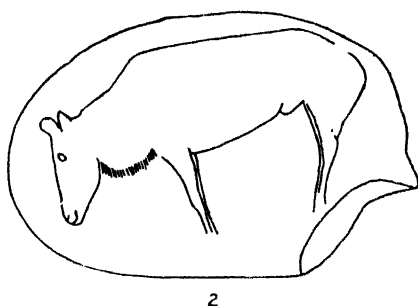


OBVERSE AND REVERSE SURFACES OF ENGRAVED PEBBLE FOUND AT LA
COLOMBIÈRE

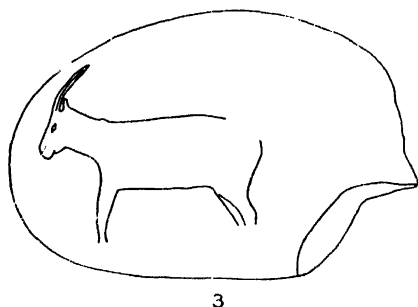
(See explanation of plates, p. 368.)



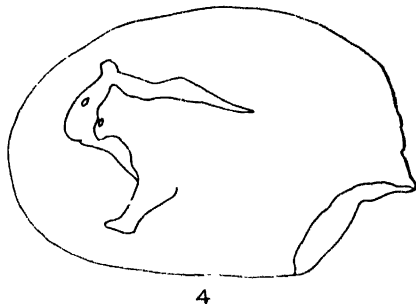
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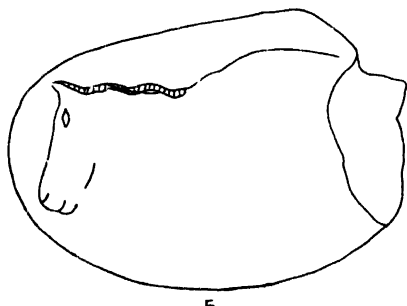
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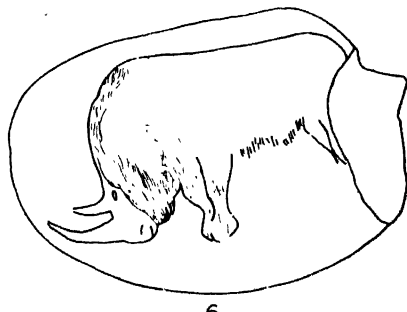
3



4



5



6

OUTLINE DRAWINGS OF ANIMALS ENGRAVED ON PEBBLE FOUND AT LA COLOMBIÈRE
(See explanation of plates, p. 368.)

ACKNOWLEDGMENTS

On behalf of the expedition, it is my pleasure to take this opportunity of thanking Professor Marcel Thorat, Director of the Laboratoire de Géologie, Faculté des Sciences de l'Université de Lyon, and Dr. Jean Viret, Director of the Muséum des Sciences Naturelles, Lyon, for their generous assistance and kind cooperation in connection with our investigations at La Colombière. It is also my privilege to thank Messrs. Joe E. Cason and Raymond H. Thompson, graduate students in the Department of Anthropology, Harvard University, for their expert help in deciphering the outlines of the animals engraved on the La Colombière pebble and reproduced on plates 6 and 7 of this article.

EXPLANATION OF PLATES

PLATE 1

General view of the rock-shelter of La Colombière showing the Late Pleistocene terraces of the Ain Valley in the vicinity of Poncin. The site, which is 46 meters long and some 12 meters wide, faces due south and directly overlooks the Ain River.

PLATE 2

La Colombière. Photograph taken by Dr. Mayet and M. Pissot in April 1913, showing the stratification revealed in a trench dug in the western end of the site.

PLATE 3

1. The site looking east, showing the undisturbed surface of the deposits after clearing. In the left foreground what appeared to be the top of a filled-in lower cave may be noted.

2. A deep trench, the outer or southern half of which was 2 meters wide, was dug through the river-laid terrace deposits at La Colombière to determine whether or not the site had been occupied prior to its invasion by the river in Late Pleistocene times. Note the rails and trucks, used for removing the excavated material, in the foreground.

PLATE 4

1. Near the rear wall of the rock-shelter the width of the main trench was expanded to 4 meters. Bedrock was finally reached below a total thickness of 11.85 meters of river-laid sands, silts, and gravels, of which the so-called La Colombière terrace was formed. There was no evidence of an early occupation of the site.

2. Section near the western end of La Colombière showing the intimate and direct association of the gravelly occupation layers with the sands laid down when the Ain River invaded the site during the late stages of the formation of the 20- to 23-meter terrace.

PLATE 5

1. Broken Magdalenian bone object perforated at one end and decorated with chevron pattern crossed on one side by parallel lines.

2. The interesting engraved pebble described in the accompanying text was found in the main (Upper Aurignacian/Gravettian) occupation layer at La

Colombière in direct association with an extensive hearth (diameter: 2 m.; thickness: 40 cm.), on the surface of which the meter scale is resting, as shown in the photograph.

PLATE 6

The beautifully engraved pebble discovered during the 1948 season in the Upper Aurignacian occupation layer at La Colombière, near Poncin (Ain).

Upper: The obverse surface of the pebble showing a very realistic horse, which is by far the most easily recognizable of any of the engravings on either face. In addition, there is an extremely finely drawn male reindeer (with shed antlers), an ibex, and two carnivores (possibly bear). The heads of the two former animals appear upside down on the right of the photograph. At least two other as yet unidentified ungulates may also be distinguished.

Lower: The reverse surface of the pebble on which a second horse and an outstandingly fine woolly rhinoceros are depicted. There are also the heads of two other partially completed rhinoceroses, and the outline of the body and legs of what appears to be a cervid of some type.

PLATE 7

Outline drawings of some of the most easily distinguished animals engraved on the interesting pebble found at the La Colombière rock-shelter in an Upper Aurignacian context. Nos. 1-4, upper surface; Nos. 5 and 6, lower surface. On the basis of the exceedingly skillful and very realistic portrayal of the forms represented, it is at once apparent that the drawings reproduced come from the hands of men who knew their models intimately at first hand. In particular, the engravings of the horse (No. 1) and the woolly rhinoceros (No. 6) are so remarkably alive that there is no mistaking the subjects. Note that all four legs are shown in the case of Nos. 1, 2, 3, and 6, and that the hair on the neck, forelegs, and shoulders of the rhinoceros has been cleverly arranged so as to suggest shading.

FIGURE 1

✓ Prehistoric archeology deals with the immense span of time between the first appearance of man and the beginnings of written record—a period of perhaps some 1,000,000 years' duration. As indicated on this chart, which shows the relative duration of prehistoric time, during approximately 49/50ths of this period man was in the Old Stone Age, or Paleolithic and Mesolithic stages, of cultural development. These stages cover the entire Pleistocene or Glacial Epoch, as well as much of Early Post-Glacial or Recent times. During the Pleistocene the northern regions and mountainous areas of the globe were subjected four times to the advances and retreats of the ice sheets (those of the Alps are known as Günz, Mindel, Riss, and Würm), river valleys and terraces were being formed, and profound changes were being induced in the fauna and flora of the Earth.

Throughout the entire span of the Old Stone Age (including both the Paleolithic and the Mesolithic periods) man was a food-gatherer depending for his subsistence on hunting wild animals and birds, fishing, and collecting wild fruits, nuts, and berries. On the basis of the evidence obtained to date, particularly that from western Europe, it is possible to recognize *three* main groups of fundamental traditions employed by our Stone Age ancestors in manufacturing their stone implements. These subdivisions are as follows: (a) core tool traditions, (b) flake tool traditions, and (c) blade tool traditions. The industry found in 1948 at the rock-shelter of La Colombière by the Peabody Museum of Harvard University's expedition to eastern France belongs in the *blade tool* category; typologically it appears to have close affinities with what is known as the Gravettian stage in the Upper Paleolithic sequence of western Europe.

RONNE ANTARCTIC RESEARCH EXPEDITION, 1946-1948

BY COMMANDER FINN RONNE, U. S. N. R.

[With 8 plates]

My interest in polar exploration dates from 1909, when my father, Martin Ronne, was selected to accompany Capt. Roald Amundsen to the Antarctic, on the memorable expedition on which the South Pole was first reached. That association continued until the great explorer's untimely death, after which my father went with Admiral Byrd on his First Antarctic Expedition, 1928-30. During all this time I had closely followed the detailed work involved in the planning and successful execution of polar expeditions. Martin Ronne died suddenly in Norway in 1932, in his seventy-first year. On Byrd's Second Antarctic Expedition, 1933-35, I had the good fortune to follow in my father's steps in the capacity of ski expert.

Upon my return to the United States in 1935, I began to plan for a small Antarctic expedition of my own, on which we would sledge and map the coast line from the Palmer Peninsula to the Ross Sea area. I planned to be set ashore, with four men and sufficient dog power, in the Charcot Island area by a Norwegian whaler and to be picked up by the whaler several months later on the Ross Sea side. However, an independent expedition did not prove possible at the time, and my modest plans eventually were merged into the United States Antarctic Service Expedition,² on which I acted as second-in-command of the east base, on Stonington Island, in Marguerite Bay, Palmer Land.

EXPEDITION PLANS

In May 1941, I obtained a commission in the United States Navy, in which I served until the end of hostilities. Off and on in my spare time I began formulating plans for an expedition to the old base of the United States Antarctic Service Expedition on Stonington Island, a location I considered well suited to geographical exploration, since within flying range lay the unexplored Weddell Sea coast line and perhaps the termination of the mountain axis of the Palmer Peninsula.

¹ Reprinted by permission from *The Geographical Review*, vol. 33, No. 3, 1948.

² English, R. A. J., Preliminary account of the United States Antarctic Expedition, 1939-41, *Geogr. Rev.*, vol. 31, pp. 466-478, 1941. The operations from the east base are described on pp. 469-473.

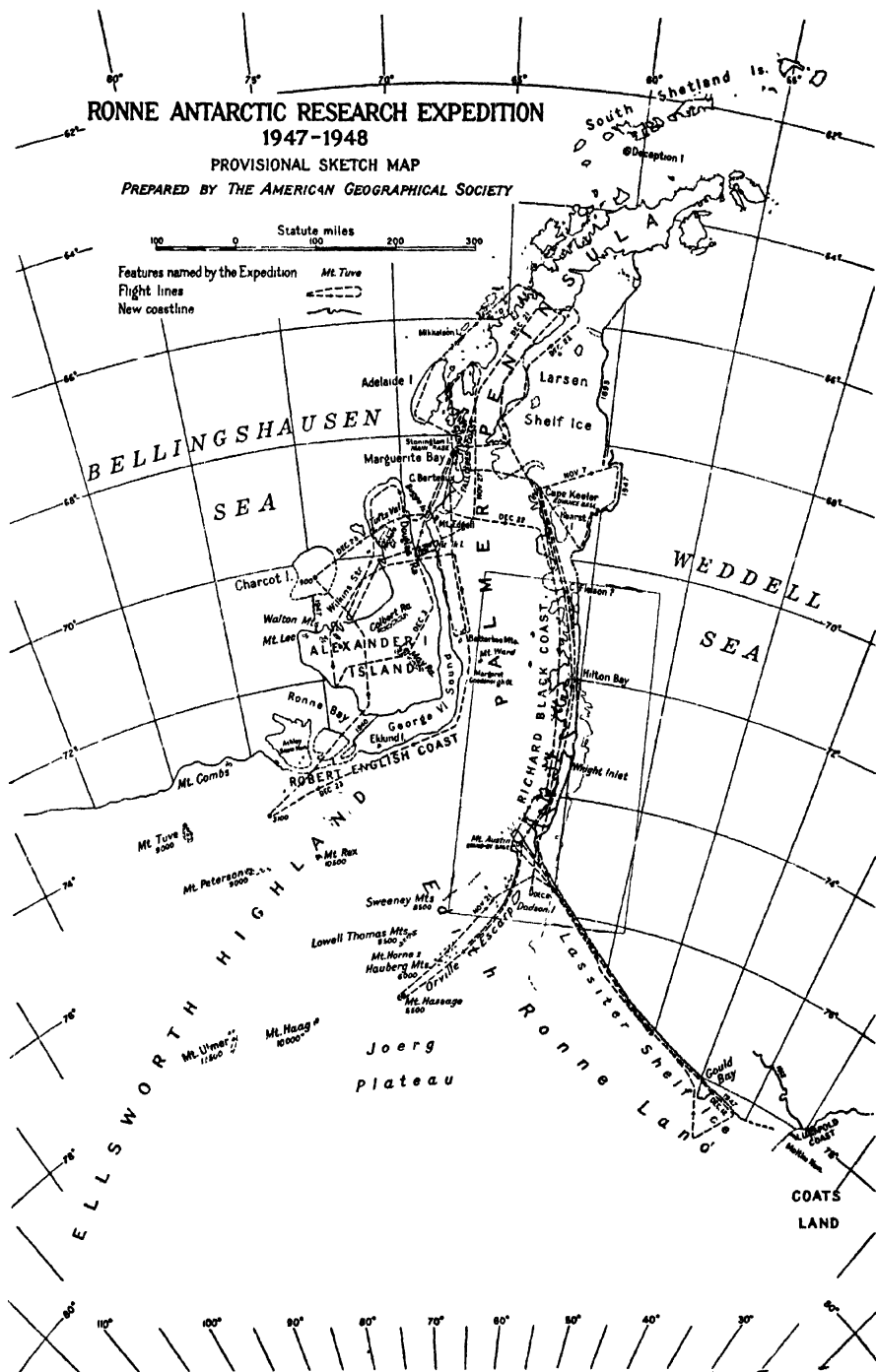
I also planned to carry on an extensive scientific program of at least a year's duration with a small group of competent men. To eliminate the necessity of sending the expedition ship back to civilization, I decided to let it freeze in at a small cove close to the base; the expedition members themselves would man it. Through Congressional action I was able to obtain from the Navy Department, on a loan basis, a sturdily constructed ocean-going wooden tug (pl. 1, fig. 1). From the Army Air Forces, Office of Research and Development, many articles of equipment were obtained for testing, including three airplanes, two snowmobiles ("weasels"), camping equipment, and numerous types of clothing.

Only those who have had the experience of planning and organizing an expedition can fully appreciate the enormous amount of work involved, especially in the matter of financial backing. I contacted many scientific organizations and foundations interested in Antarctic research, but with few concrete results. Under the auspices extended by the American Geographical Society of New York, and by selling the exclusive news rights of the expedition to the North American Newspaper Alliance, Inc., and with a few subscriptions from interested friends and a contract with the Office of Naval Research for the scientific results to be obtained, I was finally able to get the expedition under way. It was not before December 8, 1946, however, that I was definitely assured of the minimum required financial support. Through continuous hard work day and night, and spurred on by a strong determination to sail, we were ultimately able to assemble the thousands of needed articles of equipment essential for a polar expedition.

UNDER WAY

On the afternoon of January 25, 1947, we threw the mooring lines off our ship, christened *The Port of Beaumont, Texas*. The road had been long and rough, and many obstacles lay ahead, but we were on our way at last. Brief stop-overs were made at Balboa, C. Z., and Valparaiso and Punta Arenas, Chile. To avoid the dangerous roaring forties with our topside weight, which included 3 airplanes, 112 drums of gasoline and lubricating oil, and 43 northern sledge dogs, we sailed in the sheltered waters of southern Chile's inland passage. On board ship much work was done to the three airplanes, particularly the Beechcraft C-45 exploratory plane, in which a complete electrically operated trimetrogon camera unit was installed, and also a radio altimeter and extra transmitters and receivers for long-range communication. Two additional gas tanks were placed in the fuselage, so that the plane now had a maximum cruising time of 9 hours.

Our passage between Cape Horn and Marguerite Bay was fortunately very smooth, and we encountered only a relatively small amount



of pack ice and bergs. We anchored off our main base in Stonington Island on March 12, 1947 (pl. 1, fig. 1). Shortly before my departure from the United States, I had learned through the Department of State that, 2 years before, the British Government had established a permanent base on the island in continuance of a program begun in 1943 under wartime secrecy. It had also established and was maintaining other bases on the Palmer Peninsula. Great Britain, through the Falkland Islands, has long laid claim to this sector of Antarctica, and these five bases were under the administration of the Falkland Islands Dependencies Survey. However, it has been the policy of the United States not to recognize the claim of any government in the Antarctic, nor has the United States Government made any claims of its own.

I had knowledge that in the 6 years since the departure of the United States Antarctic Service Expedition in 1941 ships from several other countries had visited the American camp site. In 1943 the Argentine gunboat *Primero de Mayo* had visited the American base, and an Argentine ship and two Chilean vessels had been there shortly before we arrived in 1947. Upon our arrival we were greeted by the British leader, Maj. K. S. Pierce Butler, commander of the Falkland Islands Dependencies Survey, 1947-48, and later we became acquainted with the other 10 men, who were occupying their own quarters constructed about 200 yards from the American camp site. As I investigated, I was appalled at the amount of wanton damage that had been done to the three large and three small buildings constituting the American base. After much hard work the base was made livable again and occupied by our expedition (pl. 1, fig. 2).

GEORGE VI SOUND TRIP

I decided to attempt to establish an operational base at the southeast corner of George VI Sound, 300 miles to the south, before we anchored the ship in its final position for the winter freeze-in. I hoped to be able to set up a cache of gasoline, stores, and one of our two weasels at this halfway point and thus facilitate the transportation of such heavy equipment into the field at a later date. The attempt did not prove successful, and we later abandoned this location in favor of Cape Keeler, on the Weddell Coast. However, the journey did reveal some new features.

At 5 a. m. on March 23, after riding out a number of strong southeasterly gales with velocities of as much as 60 miles an hour, we hoisted anchor and steamed south along the Fallières Coast, past Cape Berteaux, to the entrance of George VI Sound. A group of islands, which I named the Bugge Islands, were found in approximately 69°10' S., 68°55' W. Three large islands, the largest about a mile

and a half long, stretched for some 5 miles in a northeasterly direction. Numerous small islands were 15 to 20 feet high, and most of them were bare. The larger islands, however, were covered with snowcaps more than a hundred feet high, though bedrock was exposed at the water's edge.

Thanks to the skillful piloting of our skipper, Commander Isaac Schlossbach, U. S. N. (ret.), who was also second-in-command of the expedition, the vessel moved steadily among the huge shelf ice and glacier-formed bergs that blocked the entrance to the sound. At 4 o'clock in the afternoon we reached 69°20' S., our farthest point, a new record for ships navigating in this region of the Antarctic. To make a landing anywhere was virtually impossible. I was unable to see the 150-foot ice wall which marks the entrance to the sound and over which I had traveled in 1940, but it was obvious that these tabular bergs had recently broken off from the shelf ice of the sound itself.³ (Our plane flights several months later revealed that the shelf edge was discharging bergs such as those among which we were now sailing and that the face of the shelf had moved back 35 miles in 7 years.) Not only did the conditions ahead offer an immediate danger to our only means of transportation back to the civilized world, but had we continued to search for a suitable landing place farther south, a sudden change in the weather so late in the season might have blown these huge bergs in upon us and blocked exit for another year. The risk was too great, so I gave orders to return to the open Marguerite Bay.

Our ship was moored in Back Bay, a cove a third of a mile from the base. As temperatures fell during the first week of May, it became safely frozen in the bay ice, and it remained so until the summer thaw of the following year partly released it from the icy grip (pl. 2, fig. 2).

WINTER PREPARATION AND TRAIL PLANS

The winter passed rapidly, and an immense amount of preparatory work had been accomplished by the time we were ready to start the field program. On July 15, I led a sledge party up to the plateau, 6,000 feet high, 17 miles east of our base to establish a meteorological station. This station was manned and operated during the entire flying season and, in conjunction with a station later established at Cape Keeler, 125 miles to the south of the Weddell Sea side, made it possible for H. C. Peterson, our meteorologist, to forecast the highly variable weather with good accuracy.

By August all three planes had been unloaded from the ship, assembled, and made ready. I intended to use the single-engine,

³ Ronne, Finn, The main southern sledge journey from East Base, Palmer Land, Antarctica, in *Reports on Scientific Results of the United States Antarctic Service Expedition, 1939-1941*, Proc. Amer. Philos. Soc., vol. 89, No. 1, pp. 12-22, 1945. This journey confirmed the insularity of Alexander I Island.

650-horsepower Norseman plane, which had been especially designed for cold-weather work, for flying gasoline caches to various points along the Weddell Coast. Weeks of continuous overcast, however, prevented us from completing this program. In November, by the time the weather had improved sufficiently for the southern exploratory flights, we had deposited 28 drums of high-octane gasoline at the Cape Keeler Advance Base.

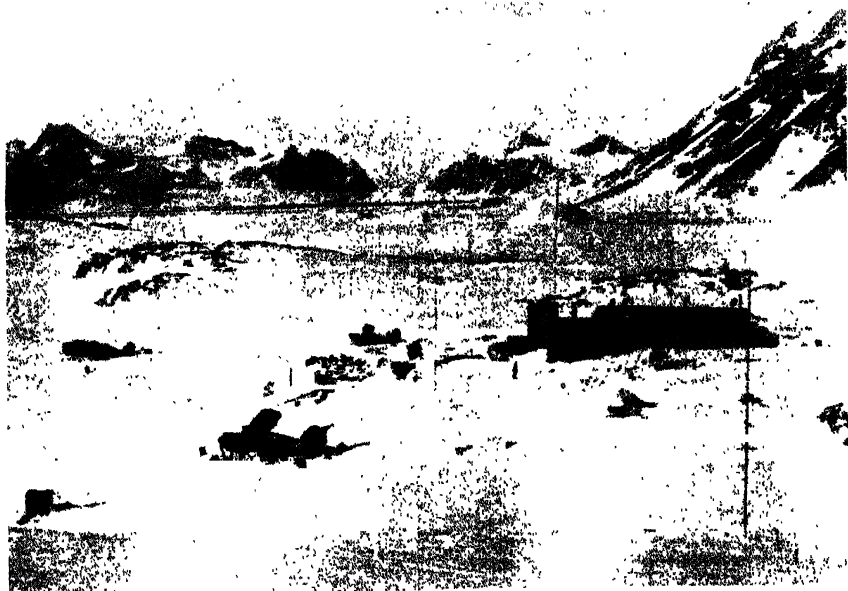
During the winter Major Butler and I had decided to cooperate in a surface field program. A joint British-American Weddell Coast sledge party consisting of four men, Major Butler and surveyor Douglas Mason of the F. I. D. S., and two members of my expedition, Walter Smith, navigator, and Arthur Owen, dog driver, were to cross the plateau by dog team to the eastern side of the Palmer Peninsula. They would sledge south along the Weddell Coast to Cape Knowles, beyond which the territory was virgin so far as surface travel was concerned, though the United States Antarctic Service Expedition had made an exploratory flight as far south as Mount Tricorn. When the surface party reached Mount Tricorn, the two Americans, now forming the Ronne Weddell Coast party, would continue southward into the unknown as far as supplies would permit, in order to establish ground control points for our aerial mapping. So long a sledge trip without the aid of supporting dog-team parties would be possible because our Norseman plane was to deposit several caches of man and dog food along the route of travel (fig. 2).

RESCUE OF BRITISH AIRMEN

As a first step the small British Auster plane took off for Cape Keeler on September 15, followed by the larger Norseman plane loaded with 3,000 pounds of trail supplies. The smaller plane was to make the initial landing in the field and pick out a suitable landing area for the heavily loaded Norseman. The Auster did not have adequate radio communication and in flight unfortunately became separated from the other plane. When the Norseman did not sight the Auster at the Cape Keeler rendezvous, a search was made, but darkness and bad weather were approaching, and Capt. James W. Lassiter had to turn back. By 10 o'clock that evening a storm had set in, and the British plane was still missing and unreported. Accordingly, I made all the facilities of my expedition available to Major Butler for his use in searching for the missing plane. Captain Lassiter and Lt. Charles J. Adams made numerous unsuccessful searching flights in the overcast weather during the next 8 days. On the ninth day, when hope was dwindling rapidly, Captain Lassiter located the three lost Britishers walking back on the sea ice 40 miles south of our base. We learned that they had actually landed at Cape Keeler on the day of the outward flight and, when they were not sighted by the Norseman, had



1. THE "PORT OF BEAUMONT, TEXAS," AT ANCHOR OFF THE MAIN BASE, STONINGTON ISLAND, MARCH 12, 1947



2. THE MAIN BASE ON STONINGTON ISLAND
Neny Island on the right.



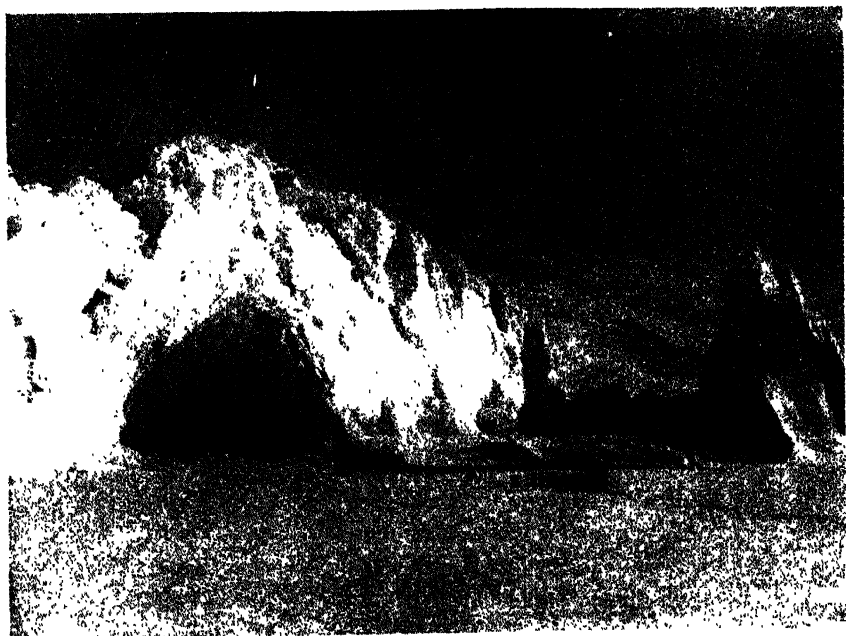
1. WEASEL HAULING THE BEECHCRAFT INTO POSITION FOR FLIGHT AT THE MAIN BASE



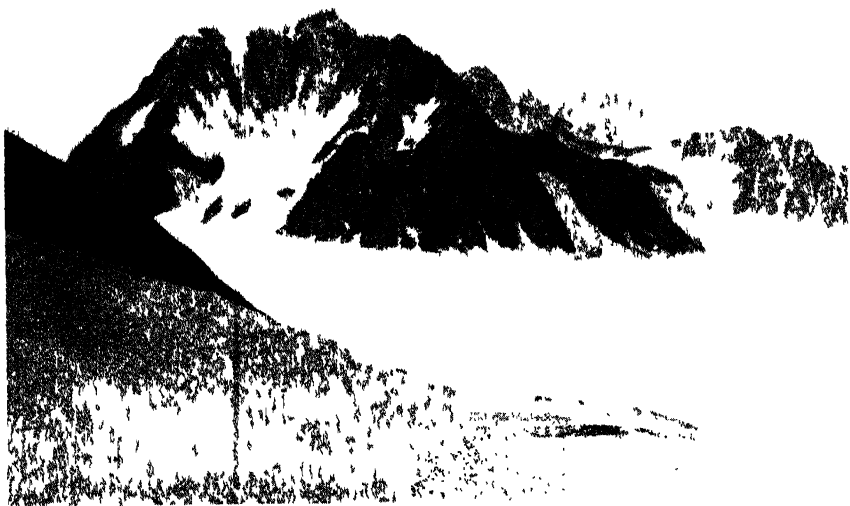
2. THE ICE-LOCKED VESSEL SEEN FROM THE GLACIER NEXT TO THE BASE
Red Rock Ridge in the background.



1. THE MAIN BASE (LEFT FOREGROUND). STONINGTON ISLAND
Ship at anchor near ice cliff.



2. DOG TEAM NEAR THE TERMINAL CLIFFS OF ONE OF THE BIG GLACIERS NEAR
THE BASE



1. AT THE ENTRANCE TO NENY TROUGH
Heavily crevassed glacier front.



2. COMMANDER RONNE, W. R. LATADY, AND CAPT. LASSITER BESIDE THE C-45
AFTER THE LONG SOUTHERN FLIGHTS



VIEW OF BASE AND NENY FJORD FROM 10,000 FEET



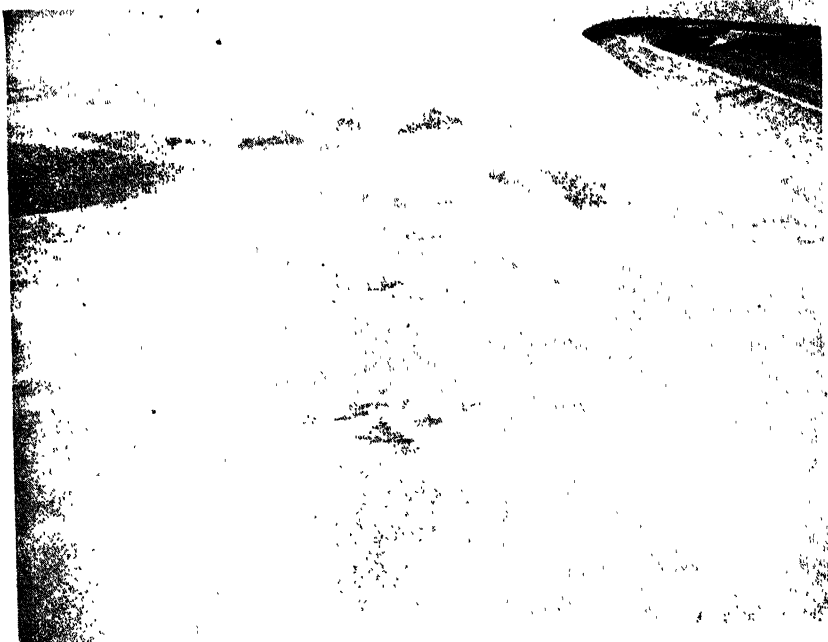
1. NEW BEDFORD INLET

K-17 photograph taken late in the evening on the first flight south. Altitude of plane, 10,000 feet, height of mountain in center of picture, 4,100 feet (taken from ground survey).

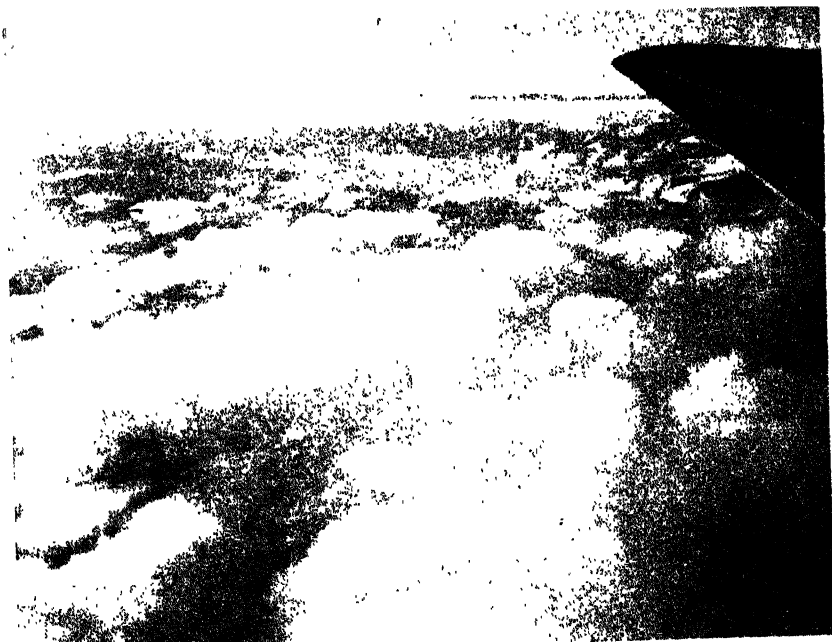


2. CAPE KEELER, ON THE WEDDELL SEA COAST

Advanced base used as an intermediate stop on flights into the unknown south.



1. WRIGHT INLET, EAST COAST OF PALMER PENINSULA
At the head is Mount Tricorn (5,450 feet).



2. HEAVY CLOUDS NEAR STEELE ISLAND

The cause of our spending a night in the field and the end of our first long flight south.



1. ALONG THE SOUTHEAST COAST OF PALMER PENINSULA
Scaife Mountains in the center.



2. LASSITER SHELF ICE, SEPARATED BY OPEN WATER FROM LOOSE PACK ICE IN
THE WEDDELL SEA

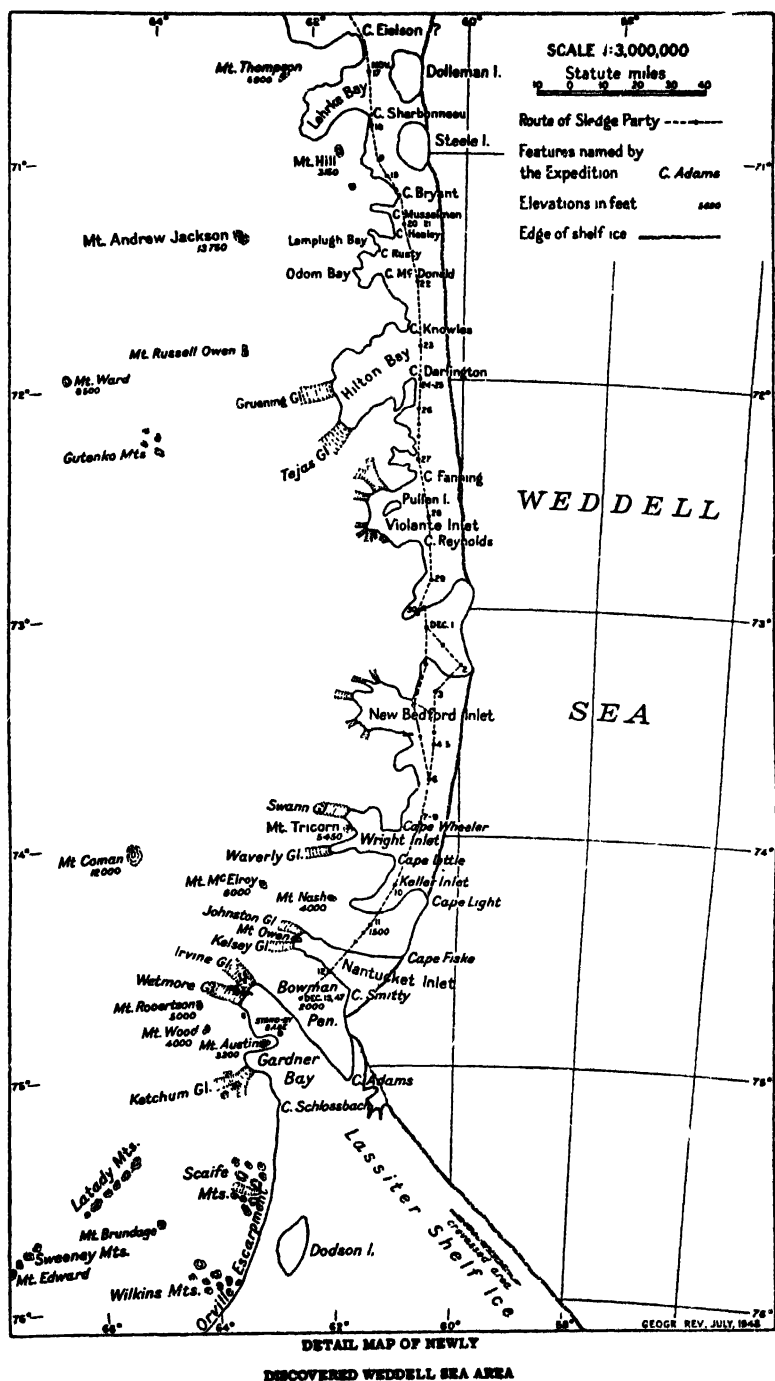


FIGURE 2.—Detailed route of the Weddell Coast sledge party, comprising British and Americans.

attempted to return to their base, lost their way in the bad weather, and crash-landed on the sea ice in Marguerite Bay. The three men were uninjured but were extremely weak from a diet of only 630 calories a day each.

FIELD PROGRAM BEGINS

Bad overcast weather continued. On September 29 a short break permitted Lassiter to fly Walter Smith and C. O. Fiske to Cape Keeler to establish our second weather station and advance base (pl. 6, fig. 2).

On September 28 the geological party, consisting of Dr. Robert L. Nichols and Robert H. T. Dodson, departed for George VI Sound and the Alexander I Island area. On October 9 the Joint British-American Weddell Coast sledge party left the main base for their long southern journey, with Smith joining them at Keeler operational base.

During October the weather continued to be unsuitable for flying, though occasional breaks of a few hours enabled the two pilots to make quick gasoline-hauling trips to Cape Keeler. Often they had to remain there for days at a time because the rapidly deteriorating weather at the main base made the return trip impossible. Finally, on November 4, I flew over to the Cape Keeler base with Captain Lassiter as pilot.

EXISTENCE OF ISLANDS OFF CAPE KEELER DISPROVED

On the morning of November 7, with Lieutenant Adams as pilot, I took off in the L-5 airplane on a short exploratory flight eastward over the Weddell Sea. After his flight from Deception Island along the Weddell Coast in 1928, Sir Hubert Wilkins reported the appearance of islands due east of Cape Keeler. On a flight from the United States Antarctic Service east base in 1940, I also had the impression of seeing islands through clouds in this same general area. We now flew due east from Cape Keeler for 100 miles, to the edge of the Larsen Shelf Ice, with its sheer cliff disappearing into the blue water. The width of this open water was about 2 miles, and beyond it, since visibility was perfect, we could see at least a hundred miles of heavy pack ice covering the Weddell Sea to the horizon. At the barrier edge we turned due south and followed the ice cliff until we sighted Cape Eielson. At the south end of Hearst Island the barrier became lower and joined the sea ice without break. At no time during our 3½-hour flight did we see signs of the reported islands. This flight, coupled with my observations of the cloud formations while we laid over at the Cape Keeler base, convinced me that on certain days clouds are formed over the open water to the east in such a way that they at times give the appearance of mountainous islands.

ACTIVITIES AT THE ADVANCE BASE

By this time the complement of the Cape Keeler base had increased to eight men: the two permanent residents, Fiske and E. A. Wood, and the six in the aviation group—Lassiter, Adams, William R. Latady, Commander Schlossbach, James B. Robertson, and myself. The tents had originally been pitched on the surface, but heavy drifts soon snowed them over. A series of interconnecting tunnels were dug to facilitate our life underground.

On their way south the four men of the Joint British-American Weddell Coast sledge party stayed at Cape Keeler for 2 days to rest their dogs. In 2 weeks they had sledged 150 miles over the plateau.

The heavy overcast weather still continued. It seemed as if we should be marooned forever in this "hellhole" of the Antarctic. Our camp was just 3 miles north of Cape Keeler, first sighted by Sir Hubert Wilkins in 1928 on his flight southward. The shelf ice extending seaward from the cape, on which our base was located, had an elevation of about 65 feet above sea level. To the south of the cape, heavy pressure areas caused by moving glaciers flowing eastward from the high plateau extended 5 miles seaward. On my flight eastward on November 7, I had observed a number of lenticular holes in the shelf ice and a deep trough running seaward in an east-northeasterly direction. The elevation of the bottom of this trough was close to sea level, though no sea leads could be seen in it.

On November 20, Adams, who had just flown over from the main base, considered that the weather was good enough for the laying of a much-needed cache for the southward-traveling sledge party. Piloting the L-5, he flew ahead to pick out a landing field for Lassiter, who piloted the larger Norseman, heavily loaded with supplies. After Adams passed Cape Eielson, he could easily identify several of the islands shown on the United States Hydrographic Office charts. They were all snow-covered except the one charted as Sharbonneau Island. A closer investigation disclosed that this extremely black rock outcrop was actually a cape, being connected with the mainland by a high snow-covered ridge. Following the map closely, Adams continued south and began searching for Darlington Island. It also proved to be a cape. At the same time, he discovered that Hilton Bay was at least 20 miles deeper than had previously been thought. Gruening Glacier flows eastward into it from the high plateau; to the south a new glacier was seen, which I named Tejas Glacier. The sledge party was located at Cape Knowles, and supplies were deposited for their use on the return journey. In overcast weather the pilots brought the planes in for a safe landing at the advance base.

FIRST LONG SOUTHERN FLIGHT

On November 21 rifts began to appear in the overcast to the south-east, and by 9 a. m. we were delighted with a cloudless sky. Weather reports radioed from the main base, the plateau weather station, and the sledge party, now 200 miles to the south of us, indicated that this was a perfect day for a long southern flight. The twin-engine, trimetrogon-equipped Beechcraft, *Ed Sweeney*, and the single-engine, cargo-carrying Norseman, *Nana*, had been ready for many days. By 9:20 a. m. the Norseman, with Adams as pilot and Schlossbach as copilot, was heading south, carrying five drums of gasoline as cargo. The heavily overloaded plane required a long run to get off the well-packed surface. Joyously I watched it head south with its precious cargo for the rendezvous in the Mount Tricorn area. Our attention was now turned to the Beechcraft.

The surface temperature was -15° F. As the engines of the Beechcraft were being warmed up, the fuel pressure lines from the carburetors to the instruments on the dashboard were found to be frozen solid. Robertson was able, however, to fix them without much delay, and with Lassiter as pilot, Latady as aerial photographer, and myself as navigator the faster Beechcraft took off from Cape Keeler, an hour and a half after the Norseman.

The visibility was perfect. Seaward I could see a 20-mile-wide strip of sea ice attached to the land, then a stretch of open water, and beyond that a belt of heavy pack ice which extended to the horizon. Mount Thompson, 5,600 feet high, was sighted close to Cape Eielson. To the west of our flight track, in the center of the Palmer Peninsula plateau, I saw several high, well-defined mountains south of the previously discovered Mount Andrew Jackson. These new mountains I named Mount Russell Owen, the Vincent Gutenko Mountains, and Mount Coman. They rose high above the plateau, and I estimated their heights to be more than 10,000 feet. Continuous radio contact was maintained between the two planes. Our rendezvous was 3,000 feet above Mount Tricorn at the head of Wright Inlet (pl. 7, fig. 1). The Norseman reached there after a flight of 3 hours and 15 minutes; the Beechcraft took only 2 hours and 30 minutes. We had no difficulty in spotting the Norseman, and together the two planes flew south along the coast line at 4,000 feet (pl. 8, fig. 1). In a few minutes we were 15 miles south of Mount Tricorn. Beneath us lay a snowy inlet, extending about 10 miles in a south-westerly direction, with rock exposures at the head. This inlet, which I named Keller Inlet, could not be seen until we were directly over it. About 30 miles south of Mount Tricorn was another inlet, which, upon examination, proved to be Nantucket Inlet (map, fig. 2). Its northernmost headland I named Cape Fiske, its southern-

most Cape Smitty, and two glaciers flowing into the inlet from the west Johnston Glacier and Kelsey Glacier. These glaciers showed only a very few crevasses where they met the inlet. Incased on both sides by mountains, they appeared like smooth, wide thoroughfares leading to the elevated land to the west.

About 50 miles south of Mount Tricorn we suddenly came upon a large bay, some 55 miles deep and 25 miles wide, Gardner Bay (map, fig. 2). Almost in the center, and connected with the head by a low-lying peninsula, was a striking snow-covered dome mountain with rock outcrops on the sides, Mount Austin (map, fig. 2). Three glaciers flowed into the bay from the high mountainous land to the west. Those coming in from the north I named Irvine and Wetmore Glaciers, and the one on the south side Ketchum Glacier. Ketchum Glacier was heavily crevassed. It was about 5 miles wide where it entered the bay, and it was joined by a tributary glacier from the southeast. The headland on the north side of the entrance to Gardner Bay I named Cape Adams, and the headland on the south side Cape Schlossbach. Rock outcropped on the east and south sides of Cape Adams and on the east side of Cape Schlossbach. Twenty-five miles to the northwest of Mount Austin was another mountain, its black, vertical cliff facing east, Mount Robertson.

LANDING IN THE FIELD

I decided to land both planes next to Mount Austin (3,200 feet), since it was easily recognizable from the air and could serve excellently as a flight stand-by base. Also, Adams had just reported from the Norseman that half the gasoline supply in his fuselage tanks had been used and the remainder would be needed for the return flight to Cape Keeler. Both planes came in for a landing less than 3 miles away from the sloping mountainside. The surface was so smooth and soft that we could not tell the exact moment when the skis touched. Once on the ground, I began making calculations. From the speed of our plane and the length of time the flight had taken, it was immediately evident that Mount Tricorn had not been correctly located on the maps—according to my rough calculations, it was about 50 miles farther to the north.

While the men were fueling the Beechcraft, I took sights with a bubble sextant to determine our exact location. Upon our return 6½ hours later, I took another series of sights, which gave me an accurate fix and established our plane base at Mount Austin as being in $74^{\circ}48'$ S., $62^{\circ}50'$ W. Our position proved that Mount Tricorn was 55 miles farther northwest than had previously been thought, and it revealed another interesting fact. Southward from Cape Knowles, in $71^{\circ}45'$ S., the entire coast line was about 30 miles farther to the west than it had previously been plotted, and its configuration was considerably different.

We were now 250 miles farther south on the Weddell Coast than any human foot had ever trod before. The Beechcraft's altimeter indicated the elevation to be 300 feet above sea level. When $2\frac{1}{2}$ drums of gasoline had been transferred from the Norseman's cargo into the Beechcraft's wing tanks, we were ready to take off on the long flight. The time was 4:10 p. m. Adams and Schlossbach, with the Norseman plane and a trail radio, were left to stand by as an additional safety and emergency precaution.

UNEXPECTED TREND OF COAST LINE

As we headed for Cape Schlossbach, we started to climb to 10,000 feet, so that the trimetrogon cameras could photograph the terrain from one horizon to the other. Visibility was unlimited as we passed the cape and headed due south to follow the trend of the mountainous coast line. A huge ice barrier could be seen disappearing over the horizon in a southeasterly direction. To the north of the barrier open water extended for 20 miles, and beyond was loose pack ice. Shortly after we rounded Cape Schlossbach, an island was sighted some 5 miles from the mainland, completely snow-covered except on its southwest side; Dodson Island is about 12 miles in length and half as much in width. It was the southernmost island that we discovered. The opposite coast I called Orville Escarpment.

Unexpectedly the mountainous coast line turned westward until its trend became 245° true. To the right, numerous mountains of various heights came into view. As we continued southwestward, the mountains were spaced farther apart. More readily definable groups took form, sharply etched against a cloudless background of white. The height of the land beneath us seemed to be gradually increasing, and at the same time the height of the rock exposures was gradually decreasing, until at our southernmost point only a gradually rising snow-covered plateau was seen. I named the mountains and groups of mountains as discovered: Sweeney Mountains with Mount Edward in the center, Scaife Mountains, Wilkins Mountains (map, fig. 2), Latady Mountains, Lowell Thomas Mountains, Mount Horne, Mount Brundage, and Mount Hassage. Mount Haag, estimated to be 11,000 feet high, was the last newly discovered mountain peak seen; beyond it, in the distance, Mount Ulmer, discovered by Lincoln Ellsworth in 1935, loomed above the horizon.

Our flight so far had proved that the mountain axis of the Palmer Peninsula gradually swings southwestward to $77^\circ 30' \text{ S.}$, 72° W. , where it dies out or merges into a higher plateau that stretches southward as Joerg Plateau. The elevation of this plateau was found to be approximately 5,000 feet, and it stretched to the limit of our visibility, which at our 10,000-foot altitude I estimated to be at least 150 miles. This meant that we actually saw the terrain as far as 81° S. It is my

opinion that this plateau gradually rises until it connects with the South Polar Plateau or terminates in a range which might be a continuation of the Queen Maud Range, to the south of the Ross Shelf Ice. This was the first of two major discoveries that together seem to eliminate the possibility of any connection between the Ross Sea and the Weddell Sea.

RETURN FLIGHT

As we turned to head back to Mount Austin, Latady dropped the American flag in the name of the United States. Our flight back paralleled the outward course 20 miles to the west, and an overlapping set of continuous photographs was taken.

When we were within 30 miles of Mount Austin, we turned southeast to follow the ice barrier. An altitude of more than 10,000 feet was maintained throughout the flight (pl. 6, fig. 1). About 50 miles from Cape Adams, 5 miles inland from the edge of the shelf ice, we passed over a highly crevassed area, 100 feet in width, which extended parallel to the edge for a distance of 30 miles. The southern side we later found to be 200 feet higher than the outer side. Similar disturbances were sighted farther inland. When we had reached approximately 77° S., 50° W., Lassiter informed me that the gasoline supply was getting low and that he felt we should return to our stand-by base (pl. 6, fig. 2). As we turned back, I noticed that the shelf ice seemed to continue on in the same southeasterly direction. There was much open water near the edge, and loose pack ice farther out. It seemed to me that a vessel could easily penetrate as far as the shelf ice itself if conditions were no worse to the north. We sighted Mount Austin without difficulty and landed alongside Adams and Schlossbach 6¼ hours after taking off. Sun and moon sights were taken to fix our position.

I realized then that another flight would be necessary to determine the extension of the shelf ice to the east and its connection with Coats Land, as explored by the German Filchner expedition in 1912. To accomplish this, more gasoline would be needed for refueling the Beechcraft. So far, the weather had provided us with few suitable flying days such as the one we were just finishing. I therefore decided that, instead of waiting in the field while the Norseman brought several loads of gasoline to us, it would be more efficient for both planes to return to Cape Keeler, refuel, and make a second trip to the south. Half an hour after we had landed at Mount Austin we were again in the air, headed north. The Beechcraft climbed to 11,000 feet, in order that Latady might photograph the coast line with the trimetrogon cameras, since he had not done so on the outward trip in order to save gasoline. Although it was 10 p. m. when we took off, the 24 hours of polar daylight made it possible for him to get good results.

We did not see the Norseman during the return, but constant radio communication was maintained between the two planes. By the time we had reached Cape Knowles, 250 miles to the north, ground fog covered the entire area ahead (pl. 7, fig. 2). Close to Steele Island, Lassiter found an opening in the fog and quickly dove through to make an emergency landing on the smooth, hard sea ice, and within 30 minutes Adams in the Norseman had been guided in by radio. We camped here until 3 o'clock in the afternoon of November 22, at which time the meteorologist at Cape Keeler informed us that Keeler weather was suitable for flying. After a brief stop at Keeler, we returned to the main base, landing at 6 p. m., just 31 hours after we had left Cape Keeler for the southern flight.

That evening Adams in the Norseman left again for the Keeler base, carrying another load of gasoline. With Fiske, Robertson, Wood, and Schlossbach, he was forced to remain there for several weeks because of continued overcast.

SECOND LONG SOUTHERN FLIGHT

The second long flight south was still foremost in my mind, but the weather reported on the daily schedules from Cape Keeler had been most discouraging—"snowed in," "blizzards with strong winds," or "overcast with ceiling zero." Finally, on the morning of December 8, Keeler reported the same good weather that prevailed at the main base. Within an hour, Lassiter, Latady, and I were in the Beechcraft headed for Keeler. Adams and Schlossbach had the Norseman loaded with a cargo of five gasoline drums and their emergency equipment and were ready to take off. The temperature was 0° F. and the air dead calm. The condition of the surface snow was very different from that on November 21, and the first three attempts to take off were unsuccessful. Finally, Schlossbach and all his emergency gear and two of the five drums had to be left behind. Even then, without the aid of any wind Adams was barely able to lift the plane into the air. It was the first time that the Norseman's plastic-shod skis had stuck to the snow. We all agreed, however, that the plastic-shod skis were far superior to metal-shod skis under most snow conditions.

The reduced load of gas made it impossible to undertake as long a flight as I had intended. My original plan had been to fly due south from Mount Tricorn for about 3 hours, then head northeast to Moltke Nunatak and the shelf ice, which we would follow back to the Norseman stand-by base. Adams had previously established a cache of 138 gallons of gasoline at Gruening Glacier for our return.

Unlike the Norseman, the Beechcraft had no difficulty in getting into the air. We climbed to 10,000 feet immediately, and by the time we passed the south end of Hearst Island, Latady had the trimetrogon

cameras systematically photographing the terrain below. Our flight track was farther inland than before, in order that he might obtain an additional set of overlapping pictures. The terrain beneath us was highly mountainous, and in places the sea ice came close to its rugged side. The 20-mile-wide belt of sea ice stretched south along the coast for 350 miles, to the great shelf ice. Numerous sea leads ran from the open water toward the mountainous coast, and frequently I detected seals sunning themselves on the ice.

After a 2½-hour flight from Keeler, the Beechcraft landed at 2:55 p. m. off the northernmost headland of Wright Inlet, which I designated Cape Wheeler. About 20 minutes later Adams circled overhead for a landing. The joint British-American Weddell Coast sledge party had reached Wright Inlet and re-formed as the Ronne Weddell Coast party. My intention was to have them stand by with Adams in the Norseman to guard our flight.

Two drums of gasoline were pumped into the Beechcraft's tanks, our emergency gear was checked, and the trimetrogon film was made ready for reloading the three cameras at intervals during the flight. As the weather ahead looked perfect, I decided to start at once. We experienced no difficulty in taking off from the sea ice where the sledge party had made their camp. Our course was laid due south.

We were steadily gaining altitude as we passed over Nantucket Inlet. Gardner Bay, with Mount Austin in the center, appeared to be about 30 miles to the west. An hour after the take-off, as we were flying slightly away from the coastal trend, we suddenly saw a heavy overcast obscuring the horizon to the south and southeast. We continued south for another 15 minutes in the hope that the visibility would improve, but instead it became much worse. Disappointing as it was, the only thing to do was to turn back to Wright Inlet and wait for more favorable weather, and 2 hours later we again landed alongside the sledge party.

The overcast that we had met to the south moved slowly northward, and by morning the visibility was less than 5 miles. That day, the 9th, the Ronne Weddell Coast party departed for the south. Their work was to obtain fixes of geographical features for correlation with the aerial photographs we had taken. The temperature remained about 0° F., and for 2 days a 40-mile wind swept over our small camp. We spent most of our restless time in sleeping bags, though we tried to take some soundings in a sea lead about 3 miles from the coast. Bottom was not reached with a 75-fathom line. On the evening of December 11 we saw that the southern horizon was beginning to clear.

THE FINAL ATTEMPT

At 3 o'clock the next morning, December 12, Adams, who had volunteered to keep an all-night weather watch, called Lassiter,

Latady, and me. He had pumped the last drum of gasoline and 30 extra gallons of gas from the Norseman's tanks into the Beechcraft and already had breakfast waiting. At 5:20 a. m. we took off, with a clear blue sky overhead. This time, however, we were unable to leave with full fuel tanks, and consequently my plan for the flight had to be slightly modified. Instead of flying due south for some distance, I decided to follow the shelf ice southeast to Moltke Nunatak and Coats Land, and then go south as far as our gas supply would permit.

Twenty minutes after the take-off we flew over the dog-team party, still sledging south. They were taking advantage of the better snow surfaces during the hours when the sun was lowest. From time to time we passed through patches of overcast, which made us lose altitude. I noticed that the area of open water to the north had increased considerably since our flight of November 21. The looseness of the pack ice as seen through my field glasses confirmed my belief that a sturdy vessel could have sailed right up to the shelf ice if conditions to the north were similar. In $78^{\circ}25' \text{ S.}$, 44° W. , we crossed a deeply indented bay, about 20 by 20 miles, which I named Gould Bay. At the head of the bay was an ice fall, heavily crevassed for a width of about a mile or more inland. Tongues of ice protruded into the head of the bay and the bay itself was partly filled with small tabular bergs, cemented together with sea ice. It reminded me very much of the Bay of Whales, in the Ross Shelf Ice in approximately the same latitude on the opposite side of the continent. Gould Bay would seem to offer a suitable place for landing a wintering party. Shortly after we had crossed the bay, overcast skies appeared straight ahead. To the north and northeast, practically ice-free water could be seen to the horizon. There was, however, some loose pack ice next to the shelf ice. By taking a sun sight to obtain a line of position, and by dead reckoning, I estimated that we were in $78^{\circ}40' \text{ S.}$, 40° W. , and about 50 miles west of Moltke Nunatak. Through a light haze we could see the easterly trend of the shelf ice.

LAND BENEATH ICE SHEET

Three hours and seven minutes after we had taken off, black clouds covered the surface beneath, and we were forced to change our course to 218° true. Through a distant clearing beyond the clouds we could see a snowy surface without visible rock outcrops. From our elevation we were unable to see either Moltke Nunatak or other mountains, and if any exist, they either are small in size or were obscured by the clouds. Our new course took us along the edge of the overcast. As this was a most important leg of our flight, I scanned the horizon with field glasses for a break of surface, but none was visible. At 8:50 a. m. Lassiter informed me that one of the fuselage tanks might run dry at any minute, and I knew, to my sorrow, that we should have to

return soon. Just then the engines missed for an instant, and Lassiter switched to a full fuel tank. Latady again dropped the American flag in the name of the United States, and I made this area part of Edith Ronne Land, which name I have given to all the newly discovered land from the farthest west seen on the November 21 flight to the farthest east seen on this flight.

I obtained a sight with the bubble sextant, which gave me the approximate position of our turning point. About 12 miles from the edge of the shelf ice Latady obtained a reading from the radio altimeter, which indicated that the surface beneath us was 700 feet above sea level; a few minutes later another reading from the radio altimeter indicated that the surface was not 300 feet above sea level; and a final reading, at the edge, showed only 100 feet. The gradual southward increase in elevation of this huge ice mass was our second important discovery. These observations, together with the observations made on the November 21 flight, the obvious obstruction which accounts for the indentation named Gould Bay, the lines of crevasses which we saw at some points extending parallel with the Lassiter Shelf Ice fringe over a width of 15 to 20 miles inland, and the fact that as seen from our most southerly position, the surface of the ice seemed to rise steadily, leads me to believe that the Antarctic continent is a single unit and is not divided by a frozen body of water extending from the Ross Sea to the Weddell Sea. The whole area had now been covered where a possible strait might exist. The line of position that I obtained at the barrier when the sun was 90° off the plane's heading fixed its location precisely.

RETURN TO MAIN BASE

While speeding over the shelf ice more than 900 miles away from our main base, we heard Kelsey come in on the radio stronger than ever. We also maintained contact from time to time with Cape Keeler and with Adams at Cape Wheeler. As we approached Mount Austin, the mountainous coast line loomed ahead once more, and Mount McElroy and Mount Nash stood well above the horizon south of Mount Tricorn. Latady was eager to obtain a second set of trimetrogon photographs of the coast line as we continued northward, so we radioed Adams to take off at once for Cape Keeler. Through my field glasses I was able to see him taxi for a take-off as we flew over Mount Tricorn at 10,000 feet. Soon afterward he was lost to sight.

When I looked southeast for the last time, I saw the 100-foot barrier disappear over the horizon. Behind us lay our most important discovery. We had followed for 450 miles the ice barrier that bounds the Weddell Sea on the south and had found that it connects with Coats Land at some distance south of $77^{\circ}50' \text{ S.}$, 36° W. , where Filchner found an ice wall in 1912. From the trend of the shelf ice as we saw it, I

conclude that Filchner saw the north side of either a huge tabular iceberg or an ice tongue that has broken off 60 miles since 1912, to its present position. Filchner reported that he built a camp on the shelf ice, which he was forced to abandon less than a month later because it had calved and was drifting northward. I named the extent of the shelf ice that we had seen in honor of my pilot Captain James W. Lassiter.

After some difficulty, because of the large patches of overcast beneath us, we located and landed at Gruening Glacier, where we pumped the 138 gallons of gasoline into the Beechcraft's fuel tanks. Meanwhile, Adams in the Norseman had gone directly to Cape Keeler and had landed, refueled, and taken all the personnel there back to the main base. We ourselves landed at the main base at 6:05 that same evening. We had been in the air 12½ hours, and in that time we had covered 1,700 miles of terrain.

THE SLEDGE PARTIES

On December 13 the Ronne Weddell Coast party reached the top of Bowman Peninsula, forming the north side of Gardner Bay. Here they verified my observations on the location of the bay and Mount Austin and made a general survey of the area. Upon their return to Mount Tricorn, this party again formed the joint British-American Weddell Coast sledge party. By utilizing the caches laid by the Norseman plane, they had no difficulty in making a good distance daily on their way back to Stonington Island. They reached the base on January 22, 1948, having covered 1,180 statute miles in 105 days on the trail.

The geological party, consisting of Nichols and Dodson with their 13-dog team, sledged southward over the sea ice of Marguerite Bay to the head of George VI Sound. Cape Nicholas on Alexander I Island was visited, and sedimentary rocks were found and studied there. On the return journey geological studies were made on Mushroom Island, Terra Firma Island, and the coast line northward to Neny Island. The men reached the main base on December 26. They had been in the field for 90 days and had covered 450 miles. After a few days in camp, Nichols, accompanied by Dodson and Latady, made a detailed geological study of Red Rock Ridge and the Neny Fiord area.

MAPPING FLIGHTS ON THE WEST SIDE OF PALMER PENINSULA

Trimetrogen flights were made on November 27 and December 3, 21, and 22, over the west and east sides of Palmer Peninsula both north and south of the main base. On the December 3 flight, over George VI Sound, cloudy weather prevented us from photographing south of the Batterbee Mountains. I still considered it would be well worth while to tie in Alexander I Island with the area south of the Batterbee

Mountains and then connect this with the Robert English Coast. These areas had not been previously photographed with trimetrogon cameras, though Eklund and I had established the ground control points in 1940. In spite of the fuel shortage, which was now becoming acute, we managed to fill the Beechcraft's fuel tanks with high-octane gasoline for a last flight.

On December 23, for the third consecutive day, the weather was excellent, with ceiling and visibility unlimited. We flew south past Mount Edgell, at the entrance to George VI Sound, and followed the sound to the Batterbee Mountains, where I saw and named the 8,500-foot Mount Ward. Mount Russell Owen, Gutenko Mountains, and Mount Coman were well defined above the Palmer Peninsula plateau. As we passed Margaret Goodenough Glacier, we changed course to 250° true, to follow the trend of the Robert English Coast westward. We passed slightly south of Eklund Island, and farther to the northwest we could see where the Sound ice terminated in Ronne Bay (named in 1940 for my father, Martin Ronne). Isolated mountain peaks lay to the south. Had the weather been more favorable at the time of his flight in 1935, Lincoln Ellsworth would certainly have seen them. Beyond Ashley Snow Nunataks (three) we flew over an escarpment with exposed rock facing the northeast. Fifty miles to the south a snow-covered mountain rose to about 10,500 feet, Mount Rex; some 60 miles west of it was Mount Peterson, tabular and about 9,000 feet, with six smaller peaks nearby.

Due west of our turning point, 74° S., $79^{\circ}35'$ W., was a partly snow-covered mountain of more than 9,000 feet, which I named Mount Tuve (approximately $74^{\circ}30'$ S., 88° W.), another, to the northwest, Mount Combs. At the turning point the radio altimeter recorded a surface elevation of 3,100 feet above sea level, which was later checked on the ground. The surface appeared level and uncrevassed, and we decided to land. The plane taxied smoothly along the soft snow. The line of position I obtained from sun shots upon landing, when correlated with the fixes I obtained on my 1940 sledge journey over some of this area, will provide ground control for the photographs we took. Twelve minutes later we were again in the air, following a course directly toward the main base. We reached Alexander I Island 20 miles to the west of the termination of the shelf ice of George VI Sound in Ronne Bay. In 71° S., 70° W., an impressive snow-covered range stretched in an east-west direction for about 40 miles. Sixty miles to the south a dark, massive range loomed majestically above the surrounding terrain. These two newly discovered mountain ranges I named respectively Colbert Range and Le May Range.

We changed our course almost to due north, then northwestward across Wilkins Strait to Charcot Island. In our flight track straight ahead we saw the Walton Mountains, about 4,000 feet, and Mount

Paul Lee loomed high above the terrain looking westward to the extreme western cape of Alexander I Island. In approximately 71° S., 75° W., I observed an ice cliff extending south from Charcot Island to the north coast of Alexander I Island. It appeared to be a connecting link between the two islands. I hope that the trimetrogon photographs will further clarify this interesting matter. Over Charcot Island our radio altimeter indicated that the surface beneath was 900 feet above sea level.

On the smooth snow surface 20 miles to the south of the three small peaks of Charcot Island we made our second landing on this flight—the first persons to set foot on that much-discussed and elusive island. The stop was just long enough for me to take a few sights. The sun was due west, and I was able to obtain a good longitudinal line of position. The sloping terrain to the south made it easy for the lightly loaded plane to take off on the last leg of our return flight. When we were in the air again, I observed much open water to the west and north of Charcot Island. It would have been possible but difficult for a ship to force its way to the island. To the east I saw many sea leads, though huge tabular bergs were still frozen in the sea's icy grip.

As we flew over the north end of Alexander I Island to cross the 10,000-foot Douglas Range, the sun still shone brightly in all directions except the east, the direction of our flight, where there was a heavy overcast. At the same time Kelsey at the main base gave us the first of a series of warnings on the sudden and rapid approach of bad weather. We crossed the island in $69^{\circ}30'$ S., by following a deep and wide valley for 40 miles. Tufts Valley, as I named it, contained a crevassed glacier that terminated on the Marguerite Bay side of the island. A 20-mile-long glacier, Nichols Glacier, is a northern branch or tributary. By the time we reached the entrance to George VI Sound we were flying in overcast. Lassiter descended below the heaviest cloud formations to an altitude of 3,000 feet, and we managed to continue northward. At Red Rock Ridge, 10 miles from the base, the weather had completely closed in around us. Fortunately, Lassiter was familiar with the terrain, and he guided the plane around the barely visible outlines of the high cliffs. At 200 feet we skimmed over icebergs floating in the open water off the ridge. Once a sudden downdraft caught the plane and forced it violently within 50 feet of the icy water beneath. Lassiter maintained his usual steady control, and a few minutes later we landed safely on the bay ice in Neny Fiord, 4 miles from base. The weasel, summoned by radio before landing, helped to bring the plane to its mooring. Gusts of wind of as much as 70 miles an hour made taxiing the plane extremely difficult. However, with two men riding on each wing to break the wind stream, we managed to get the Beechcraft moored in its usual position. I know of three men who were mighty happy to be on the ground that night!

The contrast between the weather at our departure and that on our return after more than 8½ hours of flight was striking. Once again I was deeply aware of the respect one must always hold for the sudden dangers mercilessly lurking behind the white veil that wraps this vast continent.

EVACUATION AND RETURN OF EXPEDITION

During the first week of January 1948, the three planes were dismantled and loaded aboard the ship from the bay ice. This 4-foot-thick ice, which had been used extensively as the runway for the planes, was already beginning to show signs of deterioration as a result of the summer thaw. Day by day it slowly rotted and weakened. In February strong winds with swells from the northwest broke up some of the ice, but on February 11, 4 miles of solid ice still separated the ship from the open water.

It had been my original plan to remain at the base until the middle of March, at which time I anticipated that the ice would have cleared from the Bay sufficiently to permit our return without hindrance. However, on February 12 I was informed by radio that the two Navy ice breakers then operating in Antarctic waters would visit our base. By the time they arrived, on February 19, our ship, which for some time had been surrounded by open water was again frozen in. Although winds had been blowing almost continuously for more than a week, the freezing temperatures led me to believe that the cold weather of an early fall had already overtaken the summer thaw. I remembered only too well that in 1941 this same bay ice was not gone by March 22 and we were forced to evacuate the base by two hazardous airplane flights. The risk of having to remain another year in the Antarctic, if the bay ice did not go out, was too great.

I accordingly decided to utilize the excellent opportunity offered by the presence of the ice breakers and to follow in their wake to the open sea. In this connection it is interesting to note that on April 9, 1948, I received a communication from the Governor of the Falkland Islands that stated:

Sea ice in Marguerite Bay broke up February 28, but navigation only became possible March 13. Sea freezing periodically maximum thickness one inch. Two hundred yards strip old ice still fast between Roman figure four and Neny Island.

Therefore, had I remained it would have been possible to have completed a full year of observations in the Antarctic, and to have returned without assistance, but this could not have been foreseen at the time of the ice breakers' visit.

With no difficulty whatever, they broke through to our ship. We spent all that day and the following one hurriedly completing the loading of our equipment. One of the vessels, the U. S. S. *Edisto*, went ahead to clear a wide path. The second ice breaker, the U. S. S.

Burton Island, maneuvered into position ahead of our ship and steamed into open water, and we followed in its wake.

At 4 o'clock on the afternoon of February 20, 1948, *The Port of Beaumont, Texas* rounded the stretch of ice-enclosed Stonington Island, Neny Island, and Red Rock Ridge and finally sailed into the open sea of Marguerite Bay to the west of Adelaide Island. Our year's work at this lonely outpost was now a part of history. For the third time I left the snow-covered mountains of the Antarctic continent behind me and turned my eyes northward to greener shores.

SUMMARY OF ACCOMPLISHMENTS

The accomplishments of the expedition were greater than I had hoped for. In a total flying time of 346 hours the three planes had covered 39,000 air miles of Antarctic terrain. No fewer than 86 landings had been made in the field. The planes had made extensive reconnaissances, laid caches for aviation and dog-team parties, searched for the lost British fliers, transported personnel and equipment to advanced field bases, and carried on geographical exploration and trimetrogon mapping. The program had netted a conservative total of some 250,000 square miles of terrain explored for the first time and a total of some 450,000 square miles of territory covered by 14,000 trimetrogon photographs. The photographs are now being developed, and they will be used to make new maps.

Data were obtained in various branches of science. Dr. Robert L. Nichols, head of the geology department of Tufts College, spent a total of 154 days in the field, making geological studies in the Marguerite Bay area, with the competent assistance of Robert H. T. Dodson, graduate student at Harvard, who sledged with him during the entire geological field season. Physicist Harries-Clichy Peterson's work in meteorology, cosmic rays, solar radiation, dew point, refraction, and surface radiation kept him busy for many hours of the day. He was ably assisted by Climatologist C. O. Fiske, both at the main base and when Fiske was operating the Cape Keeler advance base. Geophysicist Andrew A. Thompson made continuous comprehensive seismographic recordings with his two sensitive instruments and also carried on tidal observations and investigations in terrestrial magnetism. He spent a little more than 2 weeks at Cape Keeler taking magnetic readings; and Lt. Charles J. Adams, when in the field guarding our plane flights, was able to obtain magnetic readings from the Mount Tricorn area. These men also gave any help needed for the maintenance of the planes or the camp. Results of the geological and geophysical investigations will be available in due course.

E. A. Wood, Walter Smith, and Fiske operated the plateau weather station and the Cape Keeler advance base. Smith and Arthur Owen

were the American members of the joint British-American Weddell Coast sledge party and at Wright Inlet, with the two British members, formed the Ronne Weddell Coast party, which sledged to Gardner Bay and back to Wright Inlet. James B. Robertson, aviation mechanic, was at Cape Keeler during the flights, and Commander Isaac Schlossbach, second-in-command, when not flying as copilot with Adams, also manned the Cape Keeler base. Lawrence Kelsey was untiring at the main base radio, which was the central point for correlating information from all field units. Charles Hassage, chief engineer of our ship, *The Port of Beaumont, Texas*, in addition to running the camp during my absence, was always ready to help with the maintenance of the planes and the numerous camp chores. Mrs. Ronne assisted in the organization of the camp during my absences and acted as recorder. Nelson McClary served as ship's mate, and Dr. Donald McLean as medical officer. Chief Commissary Steward Sigmund Gutenko, U. S. N., on leave of absence with the expedition, procured and prepared all expedition food and assembled all trail and emergency food; he also gave a hand in servicing the planes when time allowed him a spare moment from the galley.

The pilots were Capt. James W. Lassiter and Lieutenant Adams, both assigned to the expedition on active duty by the Army Air Forces. Adams, as pilot of the Norseman and the L-5, hauled tons of essential equipment into the field and conscientiously and dependably backed up and stood by the Beechcraft's exploratory and photographic flights. Lassiter, in addition to piloting the Beechcraft, when flying communicated by radio with our auxiliary bases on the Weddell Coast and the main base on Stonington Island. During all the Beechcraft's flights William R. Latady checked the plane's drift meter and passed the information on to me. As aerial photographer, he was fully occupied with the operation of the trimetrogon and hand cameras and the changing of film. When not in the air, he was base photographer and machinist. The navigation end of the flights I took care of from my vantage point in the copilot's seat, which gave me a splendid view of the terrain beneath and ahead. Harry Darlington, who was accompanied by his wife, and Jorge di Georgio, Chilean, completed the personnel.

Beside carrying out the extensive program of the expedition while in the Antarctic, these volunteers manned and operated our sturdy 1,200-ton wooden vessel to and from the Antarctic, a distance of more than 14,000 miles.

To the men, whose initiative, cooperation, and loyalty contributed so greatly to the successful accomplishment of the expedition's large program, I give my sincere appreciation and gratitude.

APPENDIX

The Ronne Antarctic Research Expedition was organized with the support and good will of many individuals and organizations throughout the United States. I can mention only a few: Dr. and Mrs. Edward L. Sweeney of Evanston, Ill., and Washington, D. C., Mr. and Mrs. Allan Scaife of Pittsburgh, Pa., and John Hauberg of Rock Island, Ill., who because of their interest in exploration and science provided the necessary support. Without the sale of news rights to the North American Newspaper Alliance, Inc., a contract with the Navy Department for the results of research in various branches of science, and the many articles given me by the Research and Development Section of the Army Air Forces, the expedition would not have materialized. Representative J. M. Combs of Beaumont, Tex., was one of our strongest and staunchest supporters, and Sir Hubert Wilkins gave me many helpful ideas and suggestions. Of inestimable help, too, were Dr. Isaiah Bowman, president of The Johns Hopkins University, and Dr. Lawrence McKinley Gould, president of Carleton College. The American Geographical Society of New York, through its director, Dr. John K. Wright, extended its auspices during the days when I was planning the expedition. In addition, there are others, far too numerous to mention, who helped me in many ways. For their help I am grateful. To Capt. Harry L. Dodson, U. S. N., Dr. Dana Coman, and Dr. I. C. Gardner I am indebted for their untiring efforts to further the aims and purposes of the expedition.

NAMES OF NEW FEATURES

The new names given by me and applied to the map are: *Cape Wheeler*, after John N. Wheeler of New York; *Kelsey Glacier*, after the Kelsey family, Sacramento, Calif.; *Swann Glacier*, after W. F. G. Swann of Swarthmore, Pa.; *Mount Coman*, after Dr. Dana Coman, The Johns Hopkins University School of Medicine; *Wanerly Glacier*, after the seat of the Kasco Dog Food Company's mills; *Keller Inlet*, after Louis Keller of Beaumont, Tex.; *Cape Fiske*, after the Fiske family of Buffalo, N. Y.; *Cape Smitty*, after Walter Smith, expedition mate and navigator; *Cape Little*, after D. M. Little of Washington, D. C.; *Johnston Glacier*, after Freeborn Johnston of Washington, D. C.; *Mount McElroy*, after M. C. McElroy of Boston, Mass.; *Mount Nash*, after H. R. Nash of Pittsburgh, Pa.; *Mount Owen*, after the Owen family of Beaumont, Tex.; *Cape Adams*, after Lt. Charles J. Adams, expedition pilot; *Cape Schlossbach*, after Commander Isaac Schlossbach, second in command of the expedition; *Gardner Bay*, after Dr. I. C. Gardner of Washington, D. C.; *Wetmore Glacier*, after Dr. Alexander Wetmore of Washington, D. C.; *Wright Inlet*, after Dr. John K. Wright, Director of the American Geographical Society of

New York; *Mount Austin*, after the Texas hero; *Mount Robertson*, after James B. Robertson, expedition aviation mechanic; *Mount Wood*, after E. A. Wood, ship's engineer; *Dodson Island*, after Capt. Harry L. Dodson, U. S. N.; *Lassiter Shelf Ice*, after Capt. James W. Lassiter, expedition pilot; *Mount Russell Owen*, after Russell Owen of the New York Times; *Mount Haag*, after Joseph Haag of Todd Ship Yards, N. Y.; *Gutenko Mountains*, after the Gutenko family of Baltimore, Md.; *Latady Mountains*, after William Latady, expedition aerial photographer; *Sweeney Mountains* and *Mount Edward*, after the Sweeney family of Evanston, Ill., and Washington, D. C.; *Hauberg Mountains*, after John Hauberg of Rock Island, Ill.; *Wilkins Mountains*, after Sir Hubert Wilkins; *Scaife Mountains*, after Mr. and Mrs. Allan Scaife of Pittsburgh, Pa.; *Mount Brundage*, after Burr Brundage of Cedar Crest College, Allentown, Pa.; *Mount Horne*, after Bernhard Horne of Pittsburgh, Pa.; *Mount Hassage*, after Charles Hassage, expedition chief engineer; *Gould Bay*, after Dr. Laurence McKinley Gould, President of Carleton College; *Edith Ronne Land*, after Mrs. Ronne, expedition recorder and expedition participant; *Mount Ward*, after W. W. Ward of Beaumont, Tex.; *Mount Tuve*, after Dr. M. A. Tuve of Washington, D. C.; *Tufts Valley*, after Tufts College, Mass.; *Nichols Glacier*, after Dr. Robert Nichols' daughter, Medford, Mass.; *Niznik Island*, after the Niznik family of Baltimore, Md.; *Bugge Islands*, after the Bugge family, Molde, Norway; *Mount Thompson*, after the Thompson family of Friendship Hill Farm, Pa.; *Mount Peterson*, after Dr. Edwin Peterson of Belmont, Mass.; *Mount Rex*, after Commander Daniel Rex of Washington, D. C.; *Bowman Peninsula*, after Dr. Isaiah Bowman, President of The Johns Hopkins University, Baltimore, Md.; *Ketchum Glacier*, after Commander Gerald Ketchum, U. S. N.; *Tejas Glacier*, after the Daughters of the Republic of Texas, Beaumont, Tex.; *Cape Light*, after Dr. Richard Upjohn Light, President of the American Geographical Society; *Irvine Glacier*, after George J. Irvine, Washington, D. C.; *Orville Escarpment*, after Capt. H. T. Orville, U. S. N., Washington, D. C.; *Mount Lee*, after Admiral Paul Lee, U. S. N.; *Walton Mountains*, after Col. R. C. Walton, U. S. Marine Corps., Washington, D. C.; *Colbert Range*, after Admiral Leo Otis Colbert, Coast and Geodetic Survey, Washington, D. C.; *Le May Range*, after Gen. Curtis Le May, A. A. F.; *Cape Cole*, after W. Sterling Cole, Representative to Congress from New York.

These names have received the approval of the United States Board on Geographic Names. To the Board's Advisory Committee on Antarctic Names I am particularly indebted for promptness of consideration.

THE STATE OF SCIENCE¹

BY KARL T. COMPTON

Chairman, Massachusetts Institute of Technology Corporation

As I contemplated the task of preparing for this occasion an evaluation of science at the midcentury, I quickly came to a conviction which became more firmly established as I proceeded, and which I shall now demonstrate to you. It is that I am inadequate for the task. I am reminded, by analogy, of the Negro sprinter who when complimented on his running of 100 yards in 9½ seconds, replied: "I could run that race in 9 seconds if it wasn't for the longness of the distance and the shortness of the time." I am handicapped by the bigness of the subject and my incapacity to do it justice.

Were I a Man from Mars, visiting our planet à la Orson Welles, I should have certain advantages. In the first place I should undoubtedly be very intelligent, else I could not have contrived to make the journey and to land safely. In the second place I could view this earthly scene objectively. For the attempt to stand off, in time or space, and survey objectively our accomplishments and our shortcomings is a difficult one. Our sincerest efforts toward objectivity are unconsciously colored, not only by our own convictions and philosophy, but by those fields to which we have allied ourselves, so that the statesman tends to view everything first as a political problem; the priest, as a spiritual one; the economist, as a social one; and the scientist, as a problem for his laboratory. Nor am I, as we shall see later, an exception to this rule.

But for the moment, let us look at the world through the eyes of the Man from Mars. This, his latest invasion, is timed for the rounding of the midcentury, an accounting time when one tends to review the past for the progress made to date and to contemplate the future speculatively as to what may lie ahead.

Let us suppose our Martian had prepared himself for his trip by a study of history. He would first of all be struck by the long existence of the earth itself as a physical entity in contrast to the brief span of time in which man has played a significant role, an estimated 2 to 3 billions of years for the earth, and a brief million and a half for man.

¹ Reprinted by permission from *The Technology Review*, May 1949, edited at the Massachusetts Institute of Technology.

He would be further astonished by the tiny fragment of time we call "history" in contrast to the endless millennia of prehistory. He would note that all that modern man knows of prehistoric man has been cleverly deduced from the mute evidence left by his ancestors, often hidden in caves and dried river valleys. And finally he could not fail to be astonished by the unequal march of history itself—the long eras during which man fought and struggled and moved along, to the slow pedestrian pace of 2 or 4 miles per hour—in contrast to this century in which he has accelerated his pace until it has exceeded the speed of sound.

Our Martian's perusal of history would have acquainted him with the various stages of civilization and culture through which man has passed—the nomadic civilization of the early Semitic tribes, the intellectual ages of Greece and Rome, the primitive agrarian culture of the Middle Ages, the emergence of the crafts and guilds, the cultural renaissance of the Western world, and the rise of exploration and sea travel. And finally, he would view with some astonishment, no doubt, the industrial revolution of the last 100 years and its kaleidoscopic impact on succeeding decades.

But he would be unprepared, I think, in his global survey, for the strange inconsistencies and incongruities of the modern world. Having observed in his study of history a slow progression through nomadic, agrarian, handicraft, and industrial stages of economy, he would likely be surprised to find examples of all these stages still extant in various parts of the world. Or, if he had been particularly interested in the social and political emergence of man, how would he account for the vestigial remains of ancient tyranny, the oppressive burden of autocratic rule, still existing side by side with the democracies of the modern world? In short, to borrow a figure from the biologists, he would find our present-day civilization the phylogenesis of human history.

We might assume that this Mid-Century Convocation on the Social Implications of Scientific Progress, which opens today, has convened for the purpose of explaining to the Man from Mars the achievements, the trends, the problems, and the anomalies of our times. And in so doing perhaps we shall gain for ourselves a better understanding of the multiplicity of forces which have a bearing on our lives and so achieve a better orientation for the resolution of those discords that threaten further progress.

For my part, I am happy to be today the special pleader for the role of science in modern society. For I hold that science and technology are largely responsible for much that we find good in the world and are capable of being the common denominator of many things we seek to accomplish in the decades ahead.

To our visitor from Mars, I would point out that the scientist and engineer are busy not only in the laboratory and library but in many strange places on, above, and below the surface of the earth. On one of the highest peaks in America, one group of scientists measures the effects of cosmic radiation, while many feet below the surface of the earth, in a dark tunnel or at the bottom of a lake, other groups check on the cosmic bullets that pierce the surface of the earth. In bathyspheres as strange in appearance as though they themselves had come from Mars, men try new fathoms of the ocean depths. And missiles of extraordinary shape and size hurtle hundreds of miles above the earth to seek new data on the upper atmosphere and the spheres that lie above it. So that if to our neighbor, Mars, we appear as a race of ants, busy with a complex and remarkable division of labor, we must also appear as the possessors of an extraordinary intellectual curiosity—examining every aspect of our tiny globe and then projecting ourselves beyond it into the infinities of space.

The marvels thus uncovered have been so numerous and so dazzling in recent years that we have come to accept each new announcement with a certain complacency, almost indifference, as though nothing were to be wondered at. Yet these things to which we adjust ourselves so quickly as to be almost unconscious of change, and which we quickly come to count as necessities and "rights" of life, are often things which were entirely unknown to our parents or grandparents.

It is not inappropriate then, that we should take stock, at the mid-century, of exactly where we do stand in scientific achievement and of what is yet to be accomplished. For the scientist is not apt to find himself in the predicament of Alexander the Great, who wept because there were no more worlds to conquer. We shall see, I think, that much needs to be done on an ever-widening scale toward meeting the physical needs and opportunities facing mankind and that science is responsive, also, to those who see in it a method of approach to the deeper social problems of our times.

In assessing the status of science and society today, it is a temptation to use as a point of comparison the middle of the last century. Politically, the world then turned in an aura of unrest, not unlike that in which we now find ourselves. The revolutions which had swept across central Europe in 1848 with an upsurge of liberalism and self-determination had been succeeded by counterrevolutions and strong reaction of 1849 and 1850. To those seekers of freedom who had sought to introduce new concepts of human rights into the ancient monarchies of Europe, it must have seemed that their work and sacrifices had been in vain. The efforts for a democratic federation of states in Germany had failed; Austria had regained its autocratic domination of central Europe; and the progress that had been made in Italy had been lost in the tide of reaction.

Men like Garibaldi, Lamartine, and Louis Kossuth became the displaced persons of their day, and many of them sought refuge in the United States. Yet though all may have seemed lost to these valiant liberals, the receding tide of revolution had left its mark, and the smell of change was in the air.

In Great Britain, Queen Victoria had only just completed the first decade of her long reign. Things were relatively stable politically, and the industrial revolution had passed its first phase. The long train of miserable social conditions, which the first impact of the machine age had brought to the working classes, had only begun to be ameliorated. But thanks to the zeal of social reformers and enlightened industrialists, such as Robert Owens, Britain was learning how better to utilize this vast new giant in its midst and, above all, was coming to realize that economic stability was intimately associated with well-being, and that increased ability to produce on the part of working people was basic to any improvement in their standards of living.

It is hard for us now to realize from what depths these living standards have risen, thanks to those applications of science which produced the machine age. Just prior to the introduction of steam power, men, women, and children labored between 14 and 16 hours a day in poorly equipped factories; enjoyed no transportation of any kind; lived in windowless and unheated homes; and could not afford the luxury of candlelight because candles were taxed. Even the least fastidious today would be horrified at the unhygienic conditions which everywhere prevailed in the absence of even the most primitive types of sanitary facilities. In the long, 6-day weeks there was neither money nor leisure for any kind of recreation. The average number of a man's acquaintances during his entire lifetime was of the order of only 100. Intellectual and cultural activities among the poor were unheard of. The rate of infant mortality was enormous and estimated life expectancy was 30 years. Moves to better these conditions can be traced in part to the strong emotional appeal of such tales as *Oliver Twist*, *Bleak House*, and *Martin Chuzzlewit*.

In 1850 the first industrial exposition in the world was held in the Crystal Hall in London under the patronage of Queen Victoria and the Prince Consort.

For the United States, which abounded in its great expanses of unexploited land and endless national resources, there were no very difficult adjustments to make to get into the swing of the industrial revolution. It was just coming into full stride as a nation. Politically the sectional strife between the abolitionist North and the slave-holding South had come to an uneasy lull, based upon the compromise of 1850. For the time being, violently partisan points of view were submerged by the common desire to take advantage of a rapidly expanding economy.

Arthur M. Schlesinger in his chapter on midcentury America^{*} gives us the following picture of midcentury economy:

The amount of capital invested in manufacturing (including fisheries and mines) doubled, totaling more than a billion dollars on the eve of the Civil War. First in order of importance was the making of flour and meal, then boots and shoes, cotton textiles, and lumber products, with clothing, machinery, leather and woolen goods forging rapidly to the fore. In 1849, for the first time, the patents granted for new inventions passed the thousand mark, to reach nearly six times that number in 1860.

He also points out that "of the new mechanisms employed in industry the census officials in 1860 characterized the sewing machine as an altogether 'revolutionary instrument.' " From where we stand today, it is difficult to realize that a century ago perhaps the most significant tool in American industry was the sewing machine.

With respect to science and invention, the world at the last midcentury stood at the threshold of far-reaching and significant discoveries which were to render the ensuing century unparalleled in human progress.

Whitehead has observed that the greatest invention of the nineteenth century was the invention of the method of invention. He goes on to say, "in order to understand our epoch, we can neglect all the details of change, such as railways, telegraphs, radios, spinning machines, and synthetic dyes. We must concentrate on the method itself, that is the real novelty which has broken up the foundations of the old civilization. The prophecy of Francis Bacon has now been fulfilled; and man, who at times dreamt of himself as a little lower than the angels, has submitted to become the servant and minister of nature."

In physics, at the last midcentury, the scientific world stood firmly on the solid foundation of Newtonian mechanics, unaware that just ahead a series of events was taking shape which would effect a revolution in traditional thinking. In electricity, the basis had been laid by Franklin and Volta, while Oersted, Faraday, and Henry had shown the relation between electricity and magnetism. Fresnel had established the wave theory of light, and Joule had just proven the equivalence of heat and work.

But in 1850 the great evolution of the science of physics was about to begin. Robert A. Millikan summarized these events last year on the occasion of the centennial of the American Association for the Advancement of Science by mentioning three great advances: (1) the establishment by Joule, Kelvin, Mayer, and Helmholtz of the first and second laws of thermodynamics; (2) the quantitative proof of the kinetic theory of gases by Clausius, Boltzmann, and Maxwell; and (3) the publication by Maxwell in 1867 of his classic paper on

^{*} *Political and Social History of the United States*. Macmillan Company. New York, 1933.

electromagnetism. Millikan calls Maxwell "the greatest ornament of his age" and points out that "Maxwell's book has created the present age of electricity in much the same way in which Newton's Principia created, a hundred years earlier, the mechanical age in which we are still living."

The century drew to a close with four very great discoveries which have profoundly affected our own times. They are: (1) Roentgen's discovery of X-rays in 1895; (2) Becquerel's discovery of radioactivity in 1896; (3) J. J. Thomson's demonstration in 1897 of the electron as a fundamental constituent of all the atoms in the universe; and (4) the quantum theory of radiation enunciated by Planck in Berlin in 1900.

During the period in which such strides were being made in physics, the other sciences, notably chemistry, biology, and medicine, were not standing still. But, whereas research in physics had enjoyed a steady growth for the two centuries preceding the opening of the nineteenth, the other sciences lagged somewhat in their development. This was partly because in both chemistry and biology there was a strong tendency to cling to the classical teachings of the past. But, more significantly, progress in these fields and in medicine also was dependent to a large extent on the tools and processes being evolved by modern physics.

If one were to review even a partial list of the great names in the growth of chemistry prior to this century, it would be necessary to mention the Norwegians, Guldberg and Waage, who stated the law of mass action; the great Swedish chemist, Arrhenius, who advanced the theory of electrolytic disassociation; and the American, Willard Gibbs, whose phase rule contributed so much to the development of industrial chemistry. There would be the Russian, Mendeleev, who first classified the elements in the periodic table, and the Polish Marie Curie who, with her French husband, Pierre, made the important discovery of radium. Von Liebig and Wöhler would stand for organic chemistry and mention should be made of Hofmann, who may be regarded as the father of the German dye industry. To aspiring young scientists of today it should be of interest to note that one of Hofmann's students, W. H. Perkin, a boy of 17, is credited with discovering the first synthetic dye. The chemical industry in the United States today owes much of its start to basic work in dyes and synthetics which was done in Germany prior to World War I.

The emphasis which modern industry and modern warfare also have laid upon physical sciences has tended to obscure somewhat in the public eye the less spectacular advances of biology and medicine. The use of atomic power for both constructive and destructive purposes has greater interest for the public imagination than that mysterious process by which green plants convert the energy of the sun

into the substance of life. But who can say whether the answer to the secret of photosynthesis may not have more far-reaching effects on our lives and on those of generations to come?

Kenneth Mees, whose book, *The Path of Science*,³ presents a succinct review of the growth of scientific ideas, places the beginning of modern biology in 1838 with the publication by two Germans, Schleiden and Schwann, of the cell theory.

Biological sciences received enormous impetus from the publication in 1859 of Darwin's *Origin of Species*, but Darwin died without ever learning of the important work of Gregor Mendel whose great study of heredity shed such interesting light on Darwin's theories. The science of genetics which rests upon the foundation so brilliantly laid by Mendel owes much to Belgian zoologist Beneden who discovered the double sets of chromosomes in each nucleus except the reproductive cells.

It was also in this latter half of the nineteenth century that the great German pioneer bacteriologist, Robert Koch, discovered the bacilli of anthrax and tuberculosis, that the great French chemist, Louis Pasteur, did his pioneering work on germs and ferments, and the British Lord Lister developed antiseptic surgery.

Astronomy at the end of the nineteenth century was largely observational, with the discovery and cataloging of stars and nebulae, examination of the appearance of sun and planets, and precise calculations of orbits. Stellar spectra and brightness were measured with routine persistence but without interpretive theories to guide and give significance to the observations.

In the foregoing sketch of science up to the beginning of our twentieth century I have made no attempt at complete coverage; I have even omitted entire fields of science, like geology and psychology. I have not discussed practical applications, like engineering and medicine. I have only used these few examples to serve as springboards for the jump into the twentieth century, in which scientific progress has forged ahead with ever-increasing acceleration and in which the fields of science, hitherto almost separate in their development, have merged more and more toward a single all-inclusive and all-interrelated science of the forces and materials of nature.

The physicists and the chemists both started their twentieth-century research with the atom. The physicists have looked into the atom to discover how it was constructed and how its parts behaved. The chemists piled atoms together to form molecules of all degrees of complexity. The work of each reacted on the other, and physicists had to learn more chemistry and chemists more physics. And the discoveries of each provided new tools for both.

³ John Wiley & Sons, Inc., New York, 1947.

The major interest of physical science in the first dozen years of the century was in the attempt to explain natural phenomena by the behavior of electrons under the influence of electric forces. Such theories were very successful for some phenomena, and had some very important practical applications, namely, our entire modern electronics industry. But the electron alone was far from adequate to account for the universe.

Then Sir Ernest Rutherford proved that each atom has a heavy nucleus of positive electricity surrounded by electrons. Moseley in England proved by X-rays that these atomic nuclei are characterized by simple numbers: 1 for hydrogen, 2 for helium, 3 for lithium, and so on up to 92 for uranium—and these numbers were soon identified with the electric charge of the nucleus or the number of electrons outside it in the atom. Thus quantitative meaning was given to the periodic table of the chemists. Next, Bohr in Denmark and Sommerfeld in Germany applied the quantum theory to the Rutherford-Moseley atom and found the basis for explaining the spectra of light and X-rays. Henceforth spectroscopy became the most powerful tool for further atomic structure research, and such research became a major preoccupation of physicists in the 1920's.

But all during this time other scientists were experimenting with radioactivity, an interesting and puzzling subject whose only practical uses had been for making watch dials luminous, and treating with moderate success certain types of cancer. But when Rutherford in 1920 succeeded in transmuting one chemical element into another by bombarding it with fast particles from a radium source, and thus made real the ancient dream of the alchemists, a new era in science opened up. It opened slowly at first, and it was not until 1931 that such a transmutation was effected by use of a high-voltage machine. This was done by two pupils of Rutherford in Cambridge University. In that same year Ernest Lawrence at the University of California invented the cyclotron, which has proved the most productive of all atom-smashing machines to date. Also in the same year, Chadwick in England discovered another very important subatomic particle, the neutron. And still in that same year Fermi in Italy showed that neutrons are extremely potent in producing atomic transmutations in the atoms which they strike.

The quick result of the atomic nuclear research stimulated by these discoveries was the new discovery, or production in the laboratory, of more than twice as many new species of atoms as had been previously known to exist. Furthermore, whereas it was formerly thought that only a very few of the heaviest types of atoms were radioactive, it is now possible in these atom-smashing machines to produce at least one radioactive modification, or isotope, of every kind of chemical atom, and several radioactive modifications in many cases.

Now we jump to the fateful time, just 10 years ago, when the discovery of nuclear fission opened the way to the atomic bomb and atomic energy. In early January, 1939, two Germans, Hahn and Strassmann, found that an isotope of barium is produced when uranium is bombarded by neutrons. This news promptly reached Copenhagen, where it was given the true explanation as being a hitherto unsuspected phenomenon, nuclear fission, by two refugee scientists, Frisch and Lise Meitner, who had fled Germany to work with the great Danish physicist, Niels Bohr.

On January 19, Bohr arrived in the United States to deliver some lectures, and brought with him the news of this discovery of nuclear fission. By January 26 this discovery had been confirmed in four United States laboratories, in Copenhagen, and in France, and there had been a scientific conference on the subject in Washington. All this had happened within the short space of less than one month. By the end of a year more than 100 scientific articles on nuclear fission had been published.

Then, in 1940, the clouds of war shrouded the further developments in a degree of secrecy never before imposed in the field of science. This secrecy was at first entirely self-imposed by the scientists themselves, who conceived of the military applications of nuclear energy before either officialdom or industry even knew of the existence of this new phenomenon. The project barely survived the skepticism with which it was initially received by many of the nonnuclear scientists and engineers who became concerned with it, but by the end of 1942 its potentialities had become well established and the great Manhattan Project was undertaken, with close cooperation between the carefully selected scientific groups from the United States, the United Kingdom, and Canada.

The rest of the story is now written into the history of the dramatic ending of World War II with Hiroshima and Nagasaki; of the efforts to turn atomic energy into an instrument, through international control, for the maintenance of permanent peace; and of the current work under our Atomic Energy Commission to develop peacetime uses of atomic energy and radioactivity which are already beginning to influence the processes of industrial production and medical practice, and to open entirely new fields of exploration in chemistry, geology, metallurgy, physiology, botany, and agriculture. On the horizon still uncertainly loom the possibilities of useful production of power for ship or aircraft propulsion and other special applications of heat and power.

In this story we see the sudden merging of the results of many lines of investigation which had previously proceeded almost independently: 50 years of research on radioactivity; 20 years' development of high-voltage machines; the equivalence of mass and energy announced by

Einstein as early as 1905 as part of his theory of relativity; several decades of study of cosmic rays; 50 years' development of electronics; the whole modern art of chemical separation; the science of radiology whose impetus had come from medical applications of X-rays and the rays from radium; the most modern refinements of metallurgy, of chemical and electrical engineering. And the practical consummation of the atomic-energy objectives has called upon the highest skills of engineering design and instrumentation. It is truly an exciting picture!

I might have described many other scientific achievements of our century, such as the synthesis of complicated organic chemicals; the developments in aerodynamics or those like radio, radar, and television in the field of communications; the exciting new discoveries of hormones and their influence on physiological and emotional processes in animals and man; or the growth of the automobile industry which has so profoundly influenced our personal lives and our business operations. But I elected to dwell at length on this story of atomic energy for several reasons. It is the most striking scientific and technological development of our century; it best illustrates the methods of scientific discovery and its practical application; from it can be drawn many lessons, some of which I would mention.

The first lesson is the cooperative character of scientific progress, depending on the stimulating interplay of ideas and the accumulation of facts and skills contributed by many scientists. In my survey of nuclear science progress I mentioned only some of the most significant steps in the progress, but back of it all and filling in the gaps was the work of some thousands of other research workers.

A second lesson is the unpredictable and uncontrollable origin of the new ideas and discoveries which produce scientific progress. It was to emphasize this point that I mentioned the origins of the major discoveries which led up to the atomic-energy program. Many scientists from many parts of the world contributed the building blocks which, piled each on the ones below, completed the structure. The fact that it was done so quickly is explained by the quick and free channels of communication, often supplemented by personal acquaintance, which have traditionally characterized the scientific fraternity the world over. It is more than tragic that any nation should seek to restrain the great flow of knowledge across the world or, within national boundaries, should seek to direct its course or make it subservient to the current politics of the state. That such a policy will ultimately stifle the birth and development of significant ideas is scarcely open to dispute. For nowhere more than in science is Donne's statement true "that each is a part of the maine," and the killing off of scientific ideas in one area impoverishes the world.

Engineering developments can usually be carried through in accordance with a plan carefully prepared in advance, and often this can be done most effectively by a competent self-contained group like a company or a bureau. But scientific discovery, in its very nature and as proved by experience, does not progress according to pre-conceived plan and is stifled if attempts are made to control the free initiative of the research workers or to limit the freedom of communication between them. This is one reason why most of the fundamental new scientific discoveries have originated in free environment of the universities rather than in the quite properly more controlled atmosphere of industrial or governmental laboratories. When, however, it comes to practical applications and engineering developments, then thorough planning and control are essential to efficiency. Thus the third lesson which I would draw is this: to the extent that we wish fundamental science to advance, we must maintain the maximum of opportunity for competent scientists to follow their own bent and to communicate freely with each other.

The fourth lesson is, at first sight, in apparent contradiction with the last, but actually it is not. It is that teamwork has proven extraordinarily effective in producing results. To a certain extent, of course, teamwork implies control, which I have just decried. But what I mean by a team is a group of competent and imaginative project leaders whose skills and knowledge supplement each other and are supported by the technical assistance required to carry out their ideas. Such groups actually provide the maximum opportunity for quick initiative and for stimulating interchange of ideas. As science becomes more complex, or as its practical applications come more to the fore, the advantages of such team organization become more pronounced.

The fifth lesson, which needs no amplification, is the increasing extent to which a basic advance in theory or technique in one branch of science is likely to provide new concepts or new tools which can open up new frontiers for exploration and exploitation in other fields of science or art. This is not a new idea. It was for this reason, for example, that the Rockefeller Foundation established, under the National Research Council, the great program of National Research Fellowships which were largely effective within a decade or two in raising the United States from a third-rate to a first-rate world position in science. The Rockefeller Foundation hoped, by thus stimulating advance in the fundamental sciences, to uncover new avenues of approach to medical science—a hope that has been brilliantly justified. And another lesson which can be drawn comes from the realization that an astonishing proportion of today's leaders in American science, and of the project leaders who were the key men in our great scientific pro-

gram during World War II, were men who had received their inspiration and training in independent research under this National Research Fellowship program.

Let me now conclude this address by a look to the future. I might discuss this in terms of current scientific programs. I could describe the race between the cosmic-ray scientists who, from mountain top, airplane, and balloon, seek to utilize the still unknown energies of the cosmos to search out even more of nature's fundamental secrets of matter and energy, and the high-energy machine scientists who, with Van de Graaff generator, cyclotron, betatron, and synchrotron, are reproducing cosmic phenomena in the laboratory. It remains to be seen which group will discover the most for the fewest millions of dollars. This much can be said: both groups are meeting with exciting successes, and each stimulates and supplements the other.

Or I could try to describe some of the opportunities for the use of radioactive chemical isotopes, produced by cyclotrons and atomic piles, as tools in other lines of research. Of this, Dr. Shields Warren, Director of the Division of Biology and Medicine of the Atomic Energy Commission, said at the eighth annual science talent dinner in Washington this month:

. . . an event, the scope of which can be but dimly appreciated, has recently occurred in the development of atomic energy. First, a revolutionary concept in physics has been developed and proved and active experimentation as to its potentialities is well under way. Second, a method of tagging atoms by radioactivity so that chemical and biologic processes can be followed through in great detail is now at hand. Through this radioactivity accurate measurement of minute quantities is now feasible, for as little as one million billionth of an ounce of radio phosphorus may be detected. Third, advance in knowledge of biologic effects of radiation permits changing some hereditary characteristics in plants or animals.

Or I could venture some speculations on the possible future role of synthetically manufactured hormones which, administered like insulin to a diabetic, could control the tendency to cancer, or produce a race of giants, or turn a general into a pacifist, or cure a schizophrenic.

Or I might review the interesting theories of the universe. Is it finite; is it expanding; is it still being created; what maintains the heat of the stars and how old are they; what is their internal constitution and what forces and energies account for their condition?

But such considerations are ruled out by the limitations of both my time and my knowledge. I shall therefore approach the future more as I introduced the past, in terms of some of the problems which face our society and in whose solution science may be able to assist.

In view of the prodigious strides which science and technology have made in our century, what remains to be accomplished? From our own point of view the United States might appear to be at the summit of its industrial greatness. The young country which, in 1849, was

sending its first railroads across an undeveloped territory and pouring eager thousands of its citizens into the frantic California gold rush, in 1949 has spread across a continent and developed the land from coast to coast. Its teeming agriculture has reached new heights of productivity so that we have been able to feed not only ourselves but much of the war-torn world as well. Our industries thrive, the majority of our people are well employed at good wages, and the chief danger seems to be that we may over-extend ourselves and push prosperity beyond the point of stability. At a glance, this picture would not seem to leave much for our creative energies.

A closer examination of the facts leaves less room for complacency. Not only do we have left to solve many problems of our own areas, but we have facing us also the inescapable fact of one world. Even if we were disposed to pursue our own destiny, unmindful of the rest of mankind, we have recognized that it is impossible to do so, and that our national good is strongly linked to the good of the rest of the world. This has been the philosophy underlying the Marshall Plan and of much of our postwar thinking.

One of our principal causes of concern as scientists is the grave interruption that foreign science suffered by the war, and we are anxious for its rehabilitation. The destruction of institutions and implements of learning has been a source of distress to scholars throughout the ages, and American scientists have viewed with a sense of personal loss the destruction of libraries, laboratories, and other important tools of learning as one of the sad byproducts of war.

We should like to see foreign science restored to its prewar vigor, not only in the interest of fundamental knowledge everywhere, upon which we and everyone can draw, but also because of the way in which a healthy body of science can contribute to economic and social recovery of all nations.

To my way of thinking, it would be a helpful and legitimate thing if those countries whose programs of scientific research were most seriously disrupted by the war would see fit to include funds for the rehabilitation of those programs in their requests for United States aid under the provisions of the Foreign Assistance Act of 1948. I believe that such requests should be sympathetically received, since sound plans for economic development must rest upon technology supported by fundamental research. It is not difficult to envisage the ultimate practical good to be derived from renewed investigation in such fields as utilization of human resources, food and nutrition, medical sciences, chemistry, physics, metallurgy, geology, meteorology, hydrology, engineering, and soil mechanics. If only a small percentage of Marshall-Plan funds were invested in this manner, there can be no doubt that rich returns of a long-range nature in

material matters and in good will could be anticipated, beneficial alike to the countries concerned and to the United States.

The purposeful employment of science and technology to aid in economic reconstruction following a period of disaster is no new thing. Louis XV established the first significant school for civilian education in engineering as part of a program prudently directed to restoring French economy from the depression brought on by the extravagances of Louis XIV. In similar fashion, the great École Polytechnique was established in Paris in 1795 as part of the government's program of scientific and technical education designed to repair the economic ravages of the French Revolution. For a century, at least, L'École Polytechnique was the world's outstanding center of pure and applied science, and profoundly influenced French social and economic progress.

In Germany, where the statesmen had a peculiar appreciation for the practical values of technological education, this type of school was established in part as a recovery program from the economic chaos brought on by the Napoleonic Wars, and in part as an aid in competing with Great Britain in industry and trade. The famous technical schools in Germany became the very foundation stone of its industrial progress. Of them Whitehead has said:

. . . the Germans explicitly realised the methods by which the deeper veins in the mine of science could be reached. They abolished haphazard methods of scholarship. In their technological schools and universities progress did not have to wait for the occasional genius or the occasional lucky thought. Their feats of scholarship during the nineteenth century were the admiration of the world. This discipline of knowledge applies beyond technology to pure science, and beyond science to general scholarship. It represents the change from amateurs to professionals . . .

Closer to our own day, we have the admirable example of the British, who, following World War I, established the million-pound research fund for stimulating renewed industrial activity. This marked the beginning of a great program of scientific research under private management but with governmental support which, in the results of fundamental research and creative invention, has been claimed to exceed that of the United States, at least on a per capita basis.

It follows, then, that one important task confronting science and technology today is to assist in rescuing world-wide economy from the set-back suffered during World War II. This applies not only to the other war-devastated countries, but also to our own country where also the war seriously diminished the normal supply rate of new scientists and engineers and of new scientific discovery into those stockpiles of trained technologists and new ideas which should be our most important future asset.

It is to be hoped that our leaders of public affairs, in government and business and the professions, will be no less farsighted than those statesmen of earlier days. The postwar interest in research shown by our military departments, the favorable prospects for a national science foundation, and above all the recently increased liberality of American industrial firms in support of fundamental research within and without their organizations, are all encouraging signs.

An aspect of such problems which is in the traditional spirit of American altruism, but which is also of long-range bearing on our own welfare, was ably stated by the President in point four of his inaugural address when he said:

We must embark on a bold new program for making the benefits of our scientific advances and industrial progress available for the improvement and growth of underdeveloped areas.

More than half the people of the world are living in conditions approaching misery. Their food is inadequate. They are victims of disease. Their economic life is primitive and stagnant. Their poverty is a handicap and a threat both to them and to more prosperous areas.

For the first time in history, humanity possesses the knowledge and the skill to relieve the suffering of these people.

Already notable steps along such lines have been undertaken by a number of industrial companies which have been convinced that their long-term profitable business in relatively undeveloped areas is closely linked to the improvement in the living standards of the populations of these countries, for reasons both economic and political. Hence we see skillful programs in progress, by such companies as United Fruit, the oil companies and others, not only to raise wages but, more importantly, to apply the most modern arts of medicine and public health, soil utilization, seed selection and agricultural technique, education and recreation for improving the health, prosperity, and morale of the peoples with whom they deal. The more of this that is done, the better and the safer the world will be.

One of the lessons of history is that the improvement of man's physical and environmental well-being does much to contribute to the elimination of political and social unrest, and that the reverse promotes revolution. We know also that the constructive applications of science do improve man's environmental well-being if the gains from science are fairly distributed among the people. Hence we see, in the program advocated by the President, not only a program of altruism but also of utilizing technology in the interests of political stability and peace.

This subject will be given expert treatment in one of the panel discussions tomorrow. So, in fact, will many other goals of our current technological programs, about which I had originally thought of speaking. And I can obviously do little justice to much in my few

remaining minutes. I would, therefore, simply state my credo and my conclusions by quoting two paragraphs from my recent Wallberg Lecture at the University of Toronto:

The people of our countries crave peace and security. They want protection against the perils of Nature, like floods, hurricanes, earthquakes, and droughts; and against man-made perils of transportation, fire, and group violence. Labor strives for steady employment at higher wages, shorter hours, and more comfortable working conditions. They want the quality of goods to go up and prices to go down. People want better and more adequate housing. Those in business want larger profits. Governments, in our expanding civilization, need more tax money. Everybody wants better health. Those who think much beyond the present envisage ahead what I believe to be the greatest ultimate challenge to mankind, and that not many generations in the future. It is the problem of maintaining our growing populations in the face of rapidly depleted natural resources without descent into a final world epoch of struggle for bare survival.

If we were to take the time to examine into all these needs and desires of men we would discover two facts. One is that science and engineering have positive contributions to make to every one of these requirements. The other is even more striking. I believe that technological progress is the only common denominator to them all—the only solution which can simultaneously satisfy these statements of human needs. Laws, ideologies, economic theories, ethics, and brotherly love can provide orderly distribution, reduce waste, and promote good will among men, but they cannot create the wherewithal to satisfy all the apparently conflicting demands listed above.

We must be prepared to take each step as it comes in these vast new fields which are open before us. The fact that all the answers are not immediately at hand is no reason for pessimism. It is in the American spirit of things to want to accomplish everything overnight, and in view of past triumphs of technology perhaps we may be forgiven for being sanguine of success in this venture. In the long run, it is not likely that our confidence will be disappointed.

In any event, today, as in every other time, the scientist still stands on the threshold of the unknown. Perhaps that is his greatest joy—what Huxley more than a half century ago called “the supreme delight of extending the realm of law and order even farther towards the unattainable goals of the infinitely great and the infinitely small, between which our little race of life is run.”

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